CRITICAL TECHNOLOGIES: MATERIALS

HEARING

BEFORE THE

SUBCOMMITTEE ON
TECHNOLOGIES AND COMPETITIVENESS

OF THE

COMMITTEE ON
SCIENCE, SPACE, AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

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CONTENTS

WITNESSES

	Page
June 11, 1991:	
Dr. Mary L. Goode, Senior Vice President, Technology, Allied-Signal, Inc., Morristown, New Jersey	7
Dr. Lyle H. Schwartz, Director, Materials Science and Engineering Laboratory, NIST, Gaithersburg, Maryland	18
Dr. George Millburn, Executive Vice President, National Center for Advanced Technologies, Washington, DC	48
William Reed, President, Semiconductor Equipment and Materials Institute, Mountain View, California; accompanied by Jerry Coder, Vice President, KTI Chemicals, Inc	58
Marc S. Newkirk, President and CEO, Lanxide Corp., Newark, Delaware	83

APPENDICES

I. Charter—Critical Technologies: Materials	125
II. Additional Material Submitted for the Record	127

CRITICAL TECHNOLOGIES: MATERIALS

TUESDAY, JUNE 11, 1991

U.S. HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
SUBCOMMITTEE ON TECHNOLOGY AND COMPETITIVENESS,
Washington, D.C.

The subcommittee met, pursuant to notice, at 9:37 a.m., in Room 2325, Rayburn House Office Building, Hon. Tim Valentine [chairman of the subcommittee] presiding.

Mr. VALENTINE. The subcommittee will be in order.

Good morning, ladies and gentlemen. The hearing this morning will explore critical materials and processing technologies, the cornerstone of numerous industries such as chemicals, aviation, electronics, and automobiles. Specifically, the Government's role in these critical competitive technologies, from the research and development phase to the commercial arena, will be examined.

New materials and processes are the life's blood of industrial growth and competitive success. Materials innovation has made our airplanes more efficient, saved lives in medical applications, and brought the computer age to life. Without such innovation, industries stagnate and lose sight of the future.

The Council on Competitiveness has identified several areas in materials and processes technologies where the United States' competitive position was eroding, weak, or lost, in their opinion. The National Critical Technologies Panel of the Office of Science and Technology Policy came to a similar conclusion in their 1991 report. This situation has led to the decline of numerous U.S. industries and promises to erode our market share further if the trend is not reversed.

What is the Government's role? What are the impediments to the development and commercialization of new materials and processes? Can new legislation or policy remove impediments to the commercialization process? Does the Government have a role beyond the development laboratory in the commercial arena? How can we encourage companies in the United States to take the lead in this technology on their own?

The most effective role of Government in new materials development and utilization is not clear. Today several authorities will make their observations and recommendations with regard to Government roles and/or legislation that will improve or might improve commercializing new materials and processes in the interest of U.S. competitive advantage.

Finally, given the broad range of fields covered by this hearing and the limited number of witnesses, I realize that many other

groups and individuals may want to be heard on materials issues but do not have the opportunity to testify before this subcommittee for obvious reasons. It is impossible to post a notice on a national bulletin board for this sort of thing.

Therefore, I want to say to those present and invite you to indeed pass the word that in an attempt to expand our base of knowledge in this area, we would like to invite the submittal of statements for the record of any of you who are here or any within the sound of my voice or hear of this proceeding. I don't want to open it up so that the subcommittee finds itself under a veritable paper landslide, but the Chairman and others on the subcommittee are interested in seeing to it that we have everybody's reasonable opinion on this very important subject.

With that, I'll recognize the distinguished ranking member of the subcommittee, the gentleman from Florida, Mr. Tom Lewis.

[The prepared statement of Mr. Valentine follows:]

THE HONORABLE TIM VALENTINE, CHAIRMAN TECHNOLOGY AND COMPETITIVENESS SUBCOMMITTEE

CRITICAL TECHNOLOGIES HEARING ON MATERIALS OPENING STATEMENT

Good morning ladies and gentlemen. The hearing this morning will explore critical materials and processing technologies -- the cornerstone of numerous industries such as chemicals, aviation, electronics, and automobiles. Specifically, the governments's role in these critical, competitive technologies from the research and development phase to the commercial arena will be examined.

New materials and processes are the life's blood of industrial growth and competitive success. Materials innovation has made our airplanes more efficient, saved lives in medical applications, and brought the computer age to life. Without such innovation, industries stagnate and lose sight of the future. The Council on Competitiveness has identified several areas in materials and processes technologies where the U.S. competitive position was eroding, weak, or lost in their opinion. The National Critical Technologies Panel of the Office of Science and Technology Policy came to a similar conclusion in their 1991 report. This situation has led to the decline of

numerous U.S. industries, and promises to erode our market share further if the trend is not reversed.

What is government's role here? What are the impediments to the development and commercialization of new materials and processes? Can new legislation or policy remove impediments to the commercialization process? Does the government have a role beyond the development laboratory in the commercial arena? How can we encourage companies in the United States to take the lead in this technology on their own?

The most effective role of government in new materials development and utilization is not clear. Today several authorities will make their observations and recommendations with regard to government roles and/or legislation that will improve commercializing new materials and processes in the interest of U.S. competitive advantage.

Finally, given the broad range of fields covered by this hearing and the limited number of witnesses, I realize many other groups and individuals may want to be heard on materials issues, but do not have the opportunity to testify before this Subcommittee. Therefore, in an attempt to expand our base of knowledge in this area, I would like to invite the submittal of statements for the record.

Mr. LEWIS. Thank you, Mr. Chairman.

The OSTP Report on National Critical Technologies named materials as one of six major areas critical for national needs. Using today's technology, it is possible to produce materials that have the exact properties for specific uses. This includes high-temperature resistance composites for the outer skin of the National Aerospace Plane; non-toxic, long-lasting hip joint replacements; better ceramics for more fuel-efficient automobiles; and many more.

On the other hand, the report points out that the United States needs to accelerate the development of a superior synthesis and processing technology. Moreover, the U.S. faces serious competitive challenges from Japan in several advanced materials development areas. I hope today's witnesses will discuss the proper role of the Federal Government and of the private sector regarding U.S. materials competitiveness.

Thank you, Mr. Chairman.

Mr. VALENTINE. Thank you, sir.

I have been handed an opening statement by our colleague, Congresswoman Joan Kelly Horn, which, without objection, we will insert in the record.

[The prepared statement of Ms. Horn follows:]

Opening Statement for Joan Kelly Horn
Before the Subcommittee on Technology and Competitiveness
June 11, 1991

Mr. Chairman, distinguished colleagues, and witnesses, the topic of today's hearing, materials and materials processing, is indeed timely. As one of the critical technologies cited by the Council of Competitiveness in their report "Gaining New Ground", as well as by the National Critical Technologies Panel of the OSTP (Office of Science and Technology Policy), it is imperative that we determine how to make use of new materials in our manufacturing sector. I want to thank our distinguished Chairman for scheduling this hearing.

Many of our nation's most important industries, from aerospace and automobiles to electronics and medicine, depend on the utilization of modern, lightweight, strong materials in their products.

As someone who is very concerned about the continued health and competitiveness of our automotive and aerospace industries, I am especially interested in hearing how we in Washington can facilitate the transfer of materials processing technology to our industries. This will help our entire country regain and increase the good jobs which will improve our economy and standard of living.

At a time when auto plants are closing around the nation, including some in the St. Louis area, it is vitally important that we translate our R & D lead into a manufacturing lead. Furthermore, as our defense industry adjusts to the end of the cold war, and its huge defense budgets, our defense and aerospace industries must diversify and develop new products and new markets. Modern materials are vital to this.

The promise of these materials is almost unlimited. Strong, lightweight composites for airplane and car bodies, ceramics for engines and electronic housing, resilient versatile plastics, new metals and alloys, and membranes for gas separation and pollution control are only a few of the possible technologies which could put the U.S. in a commanding position in many industries. It is necessary that we not only create these new materials, but utilize them in products which can be exported to the world.

In today's hearing, I hope the witnesses address how government can best facilitate the incorporation of new materials into products. Would consortia among various firms and perhaps university and government laboratories help? Are there particular roadblocks in current law that could be addressed legislatively? Could we benefit from international partnerships or are these likely to profit our competitors more than us? These are a few of the topics I would like to hear our witnesses discuss. I look forward to your testimony.

Mr. VALENTINE. Our witnesses today consist of the following: Dr. Mary Good, who is President of Research and Technology at Allied-Signal, who will give us an overview; Dr. Lyle Schwartz, Director of Materials and Science Engineering Laboratory, National Institute of Standards and Technology, who will present the Federal perspective; Dr. George Millburn, who is Executive Vice President, National Center for Advanced Technologies, who will speak on aeronautics; Mr. William Reed, who is President, Semiconductor Equipment and Materials International, who will address semiconductor materials; and Dr. Marc Newkirk, who I am advised is in transit, who is President and Chief Executive Officer of Lanxide, who will talk about ceramics.

Welcome, ladies and gentlemen, and we'll hear first from Dr. Good.

Let me just make the usual statement and tell you that your prepared statements will appear in the record, and we would appreciate it very much if you would summarize. We have, as you might expect, a lot of questions, and if you could summarize in about five minutes, we would appreciate it very much.

Dr. Good?

STATEMENT OF DR. MARY L. GOOD, SENIOR VICE PRESIDENT, TECHNOLOGY, ALLIED-SIGNAL, INC., MORRISTOWN, NEW JERSEY

Dr. GOOD. Thank you, sir.

First of all, I'd like to thank the subcommittee, and particularly Chairman Valentine, for the opportunity to testify.

You've asked me to provide an overview of the materials field and to try to identify some of the impediments to competitiveness which face companies like my own, and to put that in perspective, I would remind you that Allied-Signal is about a $12 billion turnover company. We have three major sectors: one in aerospace components; one in automotive components; and one in engineered materials. So I think you can understand we have an interest in the topic on the table today.

First of all, to present an overview is truly a formidable task, because the area of materials covers an enormous lot of ground, and it is difficult to capture that under a single umbrella. So what I'd like to do is to try to set in context the importance of new materials to many of our strategic manufacturing industries and to outline some of the complexities of the industry as a whole.

Now, first, materials are the basic construction components of all manufactured products, but they are not always considered as part of the product technology, which is an interesting problem in some ways. Most manufacturers rely on materials suppliers for their metals, plastics, ceramics, or composites. They evaluate the available materials, design their products around the most optimal material for the applications, and then search for the best price. This is clearly the process used in automotive applications, in appliances, structural applications, and consumer products.

Now, the materials suppliers for these high-volume applications are generally large industrial suppliers from the chemicals or the metals industry. These suppliers make their profits by continually improving their process economics and depending on volume sales.

Since the capital investment in plants is high, and the up-front research and development costs are expensive, they need large-volume sales and raw material cost positions to be successful.

This approach has worked well in the basic metals industry, and it's been very successful in the chemically based materials, such as plastics, laminates, and synthetic fibers. The chemical industry, in particular, has been most successful in creating new materials and carrying out the process research and the development necessary to make them commercially attractive. The American chemical industry in effect is a model in that they have a large balance of trade, and they have continued to provide polymer-based materials, at least, of ever-improving properties for a wide range of applications. Now, similarly, the United States led the world for decades in the processing of ferrous metals, aluminum, and base metals like nickel and copper.

Now, in all these areas, the industry was able to successfully commercialize these materials. Now, the chemical industry, in particular, continued and still does carry out substantial amounts of basic research in both the synthesis and processing of new materials. Now, the problem, though, comes in the so-called high-tech industries such as microelectronics and aerospace, and when they began to need increasing materials performance, the problem became much more complex.

Now, many chemical companies, particularly the larger ones like DuPont and Dow, carried out extensive research to discover and develop new performance materials. For example, things like Kevlar, the high-strength polymer fiber from DuPont, and Metglas, the amorphous magnetic metal from Allied-Signal, are examples. Now, the commercial problem is that these materials required extensive research in processing, and their fundamental costs put them out of the range of commodity materials. Thus, the issue is how to recover the R&D and capital investments with a relatively low-volume product.

The problem gets even more complicated if one looks at the high-performance materials needed for the next generation of microelectronics. For one example, polymeric substrates, which will allow the nanometer line widths of microcircuits of tomorrow, require very special materials design for their electronic and structural properties, and each new system will have special requirements.

Now, these so-called advanced materials must be tailored for the application, and their volume demand will be small. These same conditions exist for high-performance ceramics, high-temperature aerospace alloys, and for many of the high-performance composites for aerospace applications. Thus, the usual materials commercialization process is not applicable. Even at very high per pound prices, the low-volume materials are not economically attractive to most of the materials suppliers.

For advanced and performance materials, the competitive issue is: how do we fund the R&D and the capital required to make them? One answer is vertical integration, and that's when the component manufacturer is the materials supplier and gets his value added from the performance superiority of his device or component. Now, that's the route that was taken, for example, by the aircraft engine manufacturers who developed high-temperature,

single-crystal, super-alloy turbine blades—they did it in-house for themselves—and several electronics suppliers, like AT&T and IBM, who have perfected their own electronic materials for their products, and they get their return back on the product that they sell out the door.

Now, the basic research on which much of the materials development is based has been carried out in the universities, in the National Laboratories, and in industry. Beginning with the ARPA Materials Laboratories funded by the Department of Defense after World War II, materials research has been a focal point of significant Government funding through DOE, DOD, and the NSF. Significant amounts of that funding have been in materials research centers, engineering centers, or materials research groups.

The reason for that, it was early recognized that materials research needs to be interdisciplinary. To synthesize a material, characterize it, and design an appropriate processing technology, one needs the combined talents of chemists, physicists, computer specialists, and engineers. Some of the research centers have worked very well, and there has been a great deal of basic information from individual scientists.

However, the crucial step in materials commercialization is product development. That is the actual product design and evaluation of the material in a prototype product. This process requires close collaboration between the materials experts and the product design groups. In many of the aerospace applications, this has been accomplished with Government support, where new high-performance materials were first utilized in these advanced DOD systems.

For example, the biggest boost to advanced materials suppliers has been projects like the B-2, the ATF, and the aerospace plane. In these projects, a materials vendor could do product applications work with a prime contractor and get rapid feedback on the material's utility and know what properties needed to be improved.

Now, as has been the case before, one expects that many of these advanced materials, once proven for these demanding applications, may very well find uses in other applications. Now, if they do, that will improve the processing economics, and it will also tend to reduce prices, but that's going to be in the future for most of those materials.

Now, one comment, it's no secret that the Japanese have targeted advanced materials as the critical technologies which will lead to the control of downstream subsystem and system technologies in high-technology products. Many American companies had and some still do have the same vision. The problem is the long lead time for commercialization, the up-front R&D and capital costs, and the high economic risk associated with a performance material for a single known application at the time that it is designed.

Now, the question is: how do we protect our lead in basic materials research, and how do we get our industrial system to capitalize on that position? Surely we must continue and increase the support for university-based materials research. The manpower which is trained there is crucial to our future, as is the fundamental underlying science. For example, the new initiative from NSF on materials synthesis and processing is clearly on target, as are some of the

issues being tackled by the steering group in materials of the FCCSET Committee on Industry and Technology.

Now, this research effort, though, should emphasize interdisciplinary programs and advanced processing technology, particularly new ways for cost-effective processing. There should be close working relationships required with the materials industry so that commercial development and product development can be effectively done in a timely manner. Some mechanism for encouraging the industrial risk capital will have to be worked out—either the support of product development from DOD, which has been going on in the programs we've had previously, product development from DOE if there are areas where that makes sense, or tax incentives for experimental plants for experimental materials.

It must be remembered that the research costs for materials development is the cheapest part of the process, and that's something that gets forgotten. The real costs come from development, both the process development and the product development, and neither the universities nor the National Laboratories are equipped—and in my mind, they should not be—to do commercial development.

In conclusion of this overview, I'm optimistic about our ability to lead the world in design and utilization of new and improved advanced materials. The question comes in our being able to design the infrastructure where it is profitable to do so.

I look forward to answering your questions and providing some further comments as the discussion progresses. Thank you.

[The prepared statement of Dr. Good follows:]

SUBCOMMITTEE ON TECHNOLOGY AND COMPETITIVENESS
OF
COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY

CRITICAL TECHNOLOGIES HEARING ON MATERIALS
JUNE 11, 1991

Testimony of Mary L. Good
Senior Vice President, Technology
Allied-Signal Inc.

First, I would like to thank the Sub-Committee and Chairman Valentine for the opportunity to testify on the vital issue of the materials industry in the United States and its future. You have asked me to provide an overview of the materials field and to identify impediments to competitiveness which face companies like my own. This is a formidable task since the area of materials covers a lot of ground and is difficult to capture under a single umbrella. However, I will try to set in context the importance of new materials to many of our strategic manufacturing industries and to outline some of the complexities in the industry as a whole.

Although materials are the basic construction components of all manufactured products, they are not always considered as part of the product technology. Most manufacturers rely on material suppliers for their metals, plastics, ceramics, or composites. They evaluate the available materials, design their products around the most optional material for the applications, and then search for the best price. This is clearly the process used in automotive applications, in appliances, structural applications, and consumer products. The material suppliers for these high volume applications are generally large industrial suppliers from the chemical or

metals industries. These suppliers make their profits by continually improving their process economics and depending on volume sales. Since the capital investment in plants is high, and the up-front research and development costs are expensive, they need large volume sales and raw material cost positions to be successful. This approach has worked well in the basic metals industry and has been very successful in chemically based materials such as plastics, laminates, and synthetic fibers. The chemical industry, in particular, has been most successful in creating new materials and carrying out the process research and development necessary to make them commercially attractive. The American chemical industry is a model industry in that they have a large positive balance of trade, and they have continued to provide polymer based materials of ever improving properties for a wide range of applications. Similarly, the U.S. led the world for decades in the processing of ferrous metals, aluminum, and base metals like nickel and copper. In all of these areas, industry was able to successfully commercialize these materials. The chemical industry, in particular, continued (and still does) to carry out substantial amounts of basic research in both the synthesis and processing of new materials.

However, as the "*so-called*" high tech industries such as microelectronics and aerospace began to need increasing materials performance, the problem became much more complex. Many chemical companies, particularly the larger ones like DuPont and Dow, carried out extensive research to discover and develop new performance materials. Kevlar, the high temperature polymer fiber from DuPont, and Metglas®, the amorphous magnetic metal from Allied-Signal, are examples. The

commercial problem is that these materials required extensive research in processing, and their fundamental costs put them out of the range of commodity materials. Thus, the issue is how to recover the R&D and capital investments with a relatively low volume product. The problem gets even more complicated if one looks at the high performance materials needed for the next generation of microelectronics. Polymeric substrates which will allow the nonometer line widths of micro-circuits of tomorrow are very special materials designed for their electronic and structural properties and each new system will have special requirements. These so-called *"advanced materials"* must be tailored for the application and their volume demand will be small. These same conditions exist for high performance ceramics, high temperature aerospace alloys, and for many of the high performance composites for aerospace applications. Thus, the usual materials commercialization process is not applicable. Even at very high per pound prices, the low volume materials are not economically attractive. For advanced and performance materials, the competitiveness issue is, *" how do we fund the R&D and the capital required to make them?"* One answer is vertical integration — when the component manufacturer is the materials supplier and gets his value added from the performance superiority of his device or component. That is the route taken by the aircraft engine manufacturers who developed high temperature, single crystal, superalloy turbine blades and several electronics suppliers like AT&T and IBM who have perfected their own electronic materials for their products.

The basic research on which much of the materials development is based has been carried out in the universities, in the national laboratories,

and in industry. Beginning with the ARPA Materials Laboratories funded by DOD after World War II, materials research has been a focal point of significant government funding thru DOE, DOD and NSF. Significant amounts of that funding have been in Materials Research Centers, Engineering Centers, or materials research groups.

It was early recognized that materials research needed to be interdisciplinary. To synthesize a materials, characterize it, and design an appropriate processing technology, one needs the combined talents of chemists, physicists, computer specialists, and engineers. Some of the Research Centers have worked quite well and surely much basic information has come from individual scientists. However, the crucial step in materials commercialization is product development, that is the actual product design and evaluation of the material in a prototype product. This process requires close collaboration between the materials experts and the product design groups. In many of the aerospace applications, this has been accomplished with government support where new, high performance materials were first utilized in advanced DOD systems. For example, the biggest boost to advanced materials suppliers has been projects like the B-2, the ATF, and the Aerospace plane. In these projects, a materials vendor could do product applications work with a prime contractor and get rapid feedback on the materials utility and know what properties needed to be improved. As has been the case before, one expects that many of these advanced materials, once proven for these demanding applications, will find uses in other applications making it possible to improve processing economics and to reduce prices.

It is no secret that the Japanese have targeted advanced materials as the critical technologies which will lead to the control of downstream subsystem and system technologies in high technology products. Many American companies had, and some still do have, the same vision. The problem is the long lead time for commercialization, the up-front R&D and capital costs, and the high economic risk associated with a performance material for a single-known application.

The question is, *"How do we protect our lead in basic materials research, and how do we get our industrial system to capitalize on that position?"* Surely, we must continue and increase the support for university based materials research. The manpower which is trained there is crucial to our future as is the fundamental underlying science. The new initiative from NSF on material synthesis and processing is clearly on target as is the Steering Group in Materials of the FCCSET Committee on Industry and Technology. This research effort should emphasize interdisciplinary programs and advanced processing technology, particularly new ways for cost-effective processing. There should be close working relationships required with the materials industry so that commercial development and product development can be effectively done in a timely manner. Some mechanism for encouraging the industrial risk capital should be worked out — either the support of product development from DOD, or DOE, or tax incentives for experimental plants for experimental materials. It must be remembered that the research costs for materials development is the cheapest part of the process. The real costs come from development, both

process and product, and neither the universities nor the national laboratories are equipped (nor should they be) to do commercial development.

In conclusion, I am optimistic about our ability to lead the world in the design and utilization of new improved and advanced materials. The question comes in our being able to design the infrastructure where it is *profitable to do so.* I look forward to answering your questions and providing some further comments during the discussion.

Thank you.

DR. MARY LOWE GOOD
Senior Vice President-Technology
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Dr. Good is senior vice-president for technology at Allied-Signal Inc. in Morristown, New Jersey.

She earned her Ph.D. in chemistry at the University of Arkansas in 1955. Before joining Allied-Signal, she was professor of chemistry at the University of New Orleans and professor of materials science at Louisiana State University, where she achieved the university's highest professorial rank, Boyd Professor.

Dr. Good's memberships include the American Chemical Society, the American Institute of Chemists, and the Royal Society of Chemistry. She has been active on the boards of directors of such groups as the Industrial Research Institute, Oak Ridge Associated Universities, and the National Institute for Petroleum and Energy Research, and has served on advisory panels for the National Research Council, the National Bureau of Standards, the National Science Foundation Chemistry Section, and the National Institute of Health. She is presently a member of the Bureau of the International Union of Pure and Applied Chemistry. She was appointed to the National Science Board by President Carter in 1980 and again by President Reagan in 1986. She currently serves as Chairman of that body.

Her honors include election to membership in the National Academy of Engineering and as a Fellow for the American Association for the Advancement of Science. She received the American Institute of Chemists' Gold Medal and was chosen Scientist of the Year by Industrial Research and Development magazine. Dr. Good was appointed as a Foreign Member of the Royal Swedish Academy on Engineering Sciences in 1990, became a member of The Tau Beta Pi Association, and was awarded the Charles Lathrop Parsons Award of the American Chemical Society. She has published over 100 articles in refereed journals and is author of a book, Integrated Laboratory Sequence, published by Barnes and Noble.

Allied-Signal Inc. is a $12 billion industrial corporation with sectors in Aerospace, Automotive, and Engineered Materials (chemically based products). Dr. Good has line responsibility for the 500 person Corporate Research and Technology organization and staff responsibility for the company's overall technology portfolio.

Mr. VALENTINE. Thank you.
Dr. Schwartz?

STATEMENT OF DR. LYLE H. SCHWARTZ, DIRECTOR, MATERIALS SCIENCE AND ENGINEERING LABORATORY, NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY, GAITHERSBURG, MARYLAND

Dr. SCHWARTZ. Mr. Chairman, Mr. Lewis, I thank you for this opportunity to describe the Federal and, more specifically, NIST's role in the development of advanced materials technology.

In the fall of 1989, the National Research Council released its landmark study on materials technologies entitled "Materials Science and Engineering for the 1990s: Maintaining Competitiveness in the Age of Materials." This study addressed the issue of the viability of U.S. technology itself in the context of today's world of relative technological equals. This timely study drew important conclusions and made recommendations for action by Government, universities, and industries. I'd like to devote my observations today to two of these recommendations dealing with coordination of Government activities and funding and with the use of the Federal laboratory system.

The NRC study recommended that the Government should recognize the essential unity of materials science and engineering in its planning, funding, and coordinating activities. The Federal Government annually spends about $1.5 billion on materials research and development. The actual work is performed at universities, in Government laboratories, and by industry. This materials R&D is funded by many agencies and departments and, except for rare instances, is not interdepartmental in nature.

Information transfer to avoid duplication of effort has been pursued through an interagency Coordinating Committee on Materials—COMAT—under the auspices of the OSTP. COMAT is a subcommittee of the Committee on Industry and Technology—the CIT—one of the seven committees which now form the system known as the Federal Coordinating Committees on Science, Engineering, and Technology. COMAT, which I chair, has and continues to foster increased coordination of Federal materials research and development. I'm pleased to say that our present efforts have been strongly influenced by the input of the private sector through the NRC study on materials and subsequent follow-up analyses, which were held at four regional meetings initiated by the OSTP.

I'd now like to devote the remainder of my testimony to another of the recommendations of the NRC study. The study recommends that universities, industries, and Government laboratories should develop joint programs in areas of national importance. Government laboratories should play a central role in this effort. A number of other national governments use this approach—namely, cooperative research and development—as their foremost strategy in fostering the technology base required for their international competitiveness. My focus today is on the developing role of the U.S. Government laboratories, and in particular NIST, in such joint program development.

The resource base for materials research at U.S. Government laboratories is enormous. About 2,000 people divided equally between defense- and civilian-type laboratories are engaged in some facet of materials research. All of these laboratories are mission-oriented, with the National Institute of Standards of Technology, NIST, and its Materials Science and Engineering Laboratory, MSEL, being the only organization with a designated charter to support the industrial materials sector. Other National Laboratories, though charged with different missions, also have extensive research capabilities relevant to industrial materials technologies.

Over the last decade or so, the role of the U.S. Government laboratories has evolved toward more effective use of mission-oriented research and development to also yield benefits to industry. A series of legislative acts were approved that established the current framework for better ties with the private sector. In recent years, the U.S. has placed greater emphasis on technology transfer from its National Laboratory resources. While there has been much success in this approach, future improvements will be hindered if they are based on the premise that Government laboratories frequently produce something that industry wants, already packaged in a way that industry can use.

Under such a premise, the technology transfer goal can be only as effective as the extent to which there is a one-to-one match between industry and Federal mission-related needs. Only by being involved in the research and development can industry researchers learn about new discoveries as they are made, thus increasing the speed of technology transfer and increasing the potential for application of the technology to other industry needs.

I'll turn now to the NIST role. My written statement contains a brief resume of NIST programs in materials technology.

During the 1980s, Congress and the Administration have expanded NIST's traditional role. Acting under this broadened charter, NIST's new role in advanced materials technologies is carried out through joint technical collaborations with industry, which begin as early as possible in the R&D process. That is, industry and NIST researchers work together from the inception of the ideas up to the stage at which a technology is ripe for commercial applications. The research goal is not to create a new material or process, but to enable industry to do so more effectively.

As examples of such cooperative ventures, my written testimony describes three programs. I'd like to use my remaining time to tell you about one of these.

NIST and the Automotive Composites Consortium—the ACC—are working on a cooperative program to improve the processing of structural polymer composite materials. The ACC partnership of Chrysler Corporation, Ford Motor Company, and General Motors Corporation is aimed at developing the technology industry needs for processing reliable, cost-effective structural polymer composite materials.

The cooperative project focuses on composites made by resin transfer molding—RTM—and structural reaction injection molding—SRIM. Leading industry representatives at two NIST workshops held in recent years indicated RTM and SRIM as among the most important processing methods for the next five to 15 years.

Consequently, new NIST programs on polymer composite processing were focused on these methodologies.

These new programs have enabled the establishment of a cooperative research and development agreement with the ACC. In cooperation with the ACC, NIST researchers will develop and use computer models for both processing methods to simulate the fabrication of a complex demonstration part made by the ACC using the latest processing and performance technologies.

This collaborative effort with the ACC offers NIST researchers an opportunity to compare model predictions with data from the fabrication of a real complex part. The information also will be used to develop generic tools and procedures needed to establish RTM and SRIM processing as efficient routes for producing a variety of polymer composite parts. We anticipate that this generic information will be broadly applicable to industries other than automotive and are exploring further industrial interaction in the aerospace arena, in particular.

In summary, let me emphasize that the roles of Federal laboratories in technology transfer and in joining with industry in generic, pre-competitive research are still evolving. For NIST, with its unique role to provide appropriate support to industry, the experiences gained in this arena have emphasized the importance of two complimentary factors in assuring NIST's successful interaction with industry.

They are, first, the involvement of industry as required from the earliest planning stages of a program through planning workshops and by having industry-sponsored research associates work hand in hand with NIST scientists and engineers; and second, long-range, generic research laboratory programs at NIST must be maintained to support associated industrial research efforts.

I'll be happy to answer questions when appropriate.

[The prepared statement of Dr. Schwartz follows:]

NIST
UNITED STATES
DEPARTMENT OF COMMERCE
NATIONAL INSTITUTE OF STANDARDS
AND TECHNOLOGY

U.S. Department of Commerce

Statement of Lyle H. Schwartz

Director, Materials Science and Engineering Laboratory

National Institute of Standards and Technology

before the

Subcommittee on Technology and Competitiveness

of the

Committee on Science, Space, and Technology

U.S. House of Representatives

June 11, 1991

Mr. Chairman, Members of the Subcommittee:

I thank you for this opportunity to describe the Federal, and more specifically, NIST's role in the development of advanced materials technology.

INTRODUCTION

Management of technology is one of the big factors in the international competitiveness of American businesses; its advancement provides the basis for new industries and the maintenance or resurgence of existing ones. Equally well recognized but sometimes less well publicized, is the role of advanced materials

technologies in influencing the competitive posture of industrial manufacturing. At NIST we define advanced materials as those which share common characteristics such as unique, highly specialized properties for specific applications, high value added through the processing sequence, and predicted rapid introduction into broad application in five to fifteen years if critical technological and cost barriers can be overcome. Advanced materials may be known today because of successful laboratory scale or even pilot plant scale development, but are not yet in broad usage in commodity products. Advanced materials technology also includes methods by which existing materials can be processed more economically or through which properties and reliability can be improved. It is important to view advanced materials in the context of the application sector. For example, today's conventional materials used in one sector such as military aerospace applications, may someday be appropriately modified to become the advanced materials for the automotive industry tomorrow.

Advanced materials technology can be an enabling technology with a direct impact on the health of the manufacturing industry. Skillful exploitation of this field will help the U.S. produce and market quality manufactured products that do totally new things, or old things in much better ways.

Although the United States generally continues its leadership role in areas of basic research and fundamental understanding, we are increasingly being challenged in the processing and manufacturing developments required to bring advanced materials technologies into common application. Many studies conducted over the years have found that materials technologies are directly linked to national economic and strategic

security. The most comprehensive in recent decades are two landmark National Research Council (NRC) assessments, "Materials and Man's Needs" (1975) and "Materials Science and Engineering for the 1990s: Maintaining Competitiveness in the Age of Materials" (1989). The earlier study considered national materials technology issues in a climate in which the U.S. science and industrial technology base was thought unchallengeable. In the 1980's the tide had turned and the latest NRC assessment addressed the issue of the viability of U.S. technology itself, in the context of today's world of relative technological equals. This timely study drew important conclusions and made recommendations for action by government, universities and industry. I'd like to devote some discussion today to two of these recommendations dealing with coordination of government activities and with the use of the Federal laboratory system. These recommendations coincide with some of the issues you asked me to address in your letter of invitation.

The NRC study recommended that:

"The government should recognize the essential unity of materials science and engineering in its planning, funding, and coordinating activities."

The Federal government annually spends about $1.5B on materials research and development. The actual work is performed at universities, in government laboratories and by industry. This materials R&D is funded by many agencies and departments, and except in rare instances is not interdepartmental in nature. Information transfer to avoid duplication of effort is being pursued through an interagency coordinating

committee on materials, COMAT, under the auspices of the Office of Science and Technology Policy (OSTP). COMAT is a subcommittee of the Committee on Industry and Technology (CIT), one of the seven committees which now form the system known as the Federal Coordinating Committee on Science, Engineering, and Technology (FCCSET). COMAT, which I chair, has and continues to foster increased coordination of Federal materials research and development. I'm pleased to say that our present efforts have been strongly influenced by the input of the private sector through the NRC study on materials and subsequent follow-up analyses which were held at four regional meetings initiated by the OSTP.

The NRC study also recommended that:

- **"Universities, industry, and government laboratories should develop joint programs in areas of national importance. Government laboratories should play a central role in this effort."**

A number of other national governments use this approach -- namely cooperative research and development -- as their foremost strategy in fostering the technology base required for their international competitiveness. My focus today is on the developing role of U.S. government laboratories, and in particular NIST, in such cooperative research and development, which I believe is critical for the development of advanced materials technology.

GOVERNMENT-LABORATORY-INDUSTRY COOPERATION IN THE U.S.

Cooperative research is not a new concept, but recent times have seen a buildup in the U.S. and abroad of a plethora of these technical linkages, due in part to the complexity of modern manufacturing and the interdependence amongst industries. In this environment, R&D capital costs are substantial and return on research investments often do not justify separate technology development efforts by individual companies. Cooperative research at the pre-competitive level is viewed as one way to mitigate these problems as it entails the joining of resources, technical and financial, to pursue areas of collective interest in furtherance of specific individual needs. In effect, a form of vertical integration of requisite technical capabilities is achieved along with a significant leverage factor on individual investment.

The resource base for materials research at U.S. government laboratories is also enormous. About 2000 people, divided equally between defense and civilian type laboratories, are engaged in some facet of materials research. All of these laboratories are mission oriented, with the National Institute of Standards and Technology (NIST) and its Materials Science and Engineering Laboratory (MSEL) being the only organization with the designated charter to support the industrial materials sector. Other national laboratories, though charged with different missions, also have extensive research capabilities relevant to industrial materials technologies.

Over the last decade or so, the role of U.S. government laboratories has evolved towards more effective use of mission-oriented research and development to also yield

benefits to industry. Cognizance of the need to better utilize our national laboratory system began in the late 1970s-early 1980s period. The Packard Commission in its 1983 report emphasized the need for closer interactions between government laboratories and industry, while the 1985 report of the Young Commission on Industrial Competitiveness focused attention on technology transfer from the national laboratories. In concert, a series of legislative acts were approved that established the current framework for better ties between the private sector and the national laboratories. The Stevenson-Wydler Technology Innovation Act of 1980, the primary law facilitating access to the Federal lab system, mandated that Federal organizations and affiliated laboratories pursue technology transfer activities. Later legislation, the Federal Technology Transfer Act (FTTA) of 1986, amended the Stevenson-Wydler Act to create a legal and management framework and a decentralized approach for the commercialization of technology developed by government-owned, government-operated laboratories. The National Competitiveness Technology Transfer Act of 1989, part of the National Defense Authorization Act for Fiscal Years 1990-91, extended coverage of the FTTA to include the government-owned, contractor-operated laboratories of DOE. Executive Order 12591 issued in 1987 by President Reagan gave implementation guidelines to the Federal laboratories and directed that cooperative R&D efforts be promoted between these laboratories and the private sector.

The stated purpose of the FTTA was to foster technology transfer nationwide through the implementation of cooperative research and development agreements (CRADA's) between Federal laboratories and industrial companies. Federal participants include all major government laboratories and centers and their parent agencies. NIST has been

a major participant in the CRADA program. Since the passage of the Technology Transfer Act of 1986, NIST has signed 110 of these agreements, of which 34 are cooperative programs focused on advanced materials technologies.

In recent years, the U.S. has placed greater emphasis on technology transfer from its national laboratory resources. While there has been much success in this approach, future improvements will be hindered if they are based on the premise that government laboratories frequently produce something that industry wants already packaged in a way that industry can use. Under such a premise, the technology transfer goal can be only as effective as the extent to which there is a one-to-one match between industrial needs and the research outputs of mission oriented government laboratories. Such a match often does not occur in applied Federal research unless planning and coordination between the researcher and the intended user is involved.

CRADA's are one means for enhancing technology transfer even when there is not an upfront one-to-one match between industry and federal mission-related needs. By being involved in the research and development, industry researchers learn about new discoveries as they are made, thus increasing the speed of technology transfer and increasing the potential for application of the technology to other industry needs.

NIST pioneered cooperative research with industry starting more than 60 years ago, and well before its responsibilities were broadened by the 1988 Omnibus Trade and Competitiveness Act. NIST works collaboratively with a single company, multiple companies, trade associations, universities and other government agencies.

Cooperative ventures take several forms, from industrial consortia, to the Industrial Research Associate Program where companies pay their staff to work cooperatively with NIST scientists in our laboratories. Currently more than 200 industrial associates work each year side-by-side with NIST researchers. Projects last in duration from a few weeks to a few years, or more, until the job is accomplished. For NIST with its unique role, our researchers in turn benefit from the joint programs, learning first hand the needs and views of our industrial partners, and being better able to adjust our research directions for continuing service to industry. There are many reasons why industry has found it valuable to work with NIST. They include access to unique facilities, the broad scientific and technical base of expertise available at one laboratory, and the third party character and focus on technical issues which NIST brings to questions of standards and codes of practice. Now added to that list, as specified in the 1988 Omnibus Trade Act, is the flexibility of NIST to modify and adapt its R&D programs to become more responsive to generic industrial needs.

NEW NIST ROLE

During the 1980s, Congress and the Administration have expanded NIST's traditional role. New programs have been enacted by Congress which are intended to aid U. S. industries in developing new technologies or in improving current product quality, performance and cost, thus improving competitiveness within the international community. Using different approaches, these programs focus on a national effort to accelerate the development of pre-competitive generic technologies, and a regional effort to enhance existing manufacturing by directly transferring government developed technologies to individual companies.

One of these new approaches is the Advanced Technology Program (ATP), created in 1988 and first funded in 1990. The ATP is designed to provide matching funds for U.S. industry's development of precompetitive generic technologies with potential for broad based economic impact. It attempts to do this through industry-led research and development on generic, precompetitive, and enabling technologies. The ATP supports research and development up to the stage where technical uncertainties are reduced to permit preliminary assessment of commercial potential. The results of the research and development program should be useful in a variety of products or applications. The ATP selection criteria explicitly include:

- improving the U.S. technology base
- potential to significantly improve U.S. economic growth
- evidence that success will lead to commercialization

The first grants under this program, totalling some $9 million, have just been made to a list of recipients which includes joint ventures and individual companies. One of the programs funded is an advanced materials program in high temperature superconducting thin films. Other funded programs include a substantial materials component as a requirement to develop advanced laser sources, holographic mass storage systems, magnetoresistive memories for computer systems, and printed wiring boards. The second solicitation of proposals is expected soon.

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INDUSTRIAL TRENDS

Materials technology programs in MSEL at NIST are being developed and implemented in the context of changing characteristics of U.S. industry. Three major trends in the materials science and engineering community are fundamentally changing the process of transferring research output in materials science to industrially utilized materials. The first trend is the shift in balance from the traditional commodity materials to advanced, high technology, high value added materials which are developed specifically to satisfy unique functional or structural needs. Industries which can rapidly and successfully adopt advanced materials into their manufacturing processes to improve performance, reliability, or cost will likely be in a better position for worldwide competition.

The second trend reflects the evolutionary shift in industrial R&D leadership away from primary materials producers to materials utilization industries. For metals, especially for aerospace and transportation applications, the users or fabricators of modern, highly specialized alloys are increasingly responsible for development of new alloys and processing methodologies, and for the establishment of alloy performance data. The highly disaggregated producers of advanced ceramics cannot support the integrated research effort needed to commercialize advanced materials and depend on complementary programs in the user industries. In the composites community, the fabrication or lay-up of high performance composites is often carried out on-site by the component user and thus it is the user who does much of the research and development on the composites.

The third trend in materials technology is the increased reliance industry will have on intelligent processing of materials with remote sensing of materials characteristics to provide real time feedback to a knowledge-based computer control system to insure product quality and to improve cost competitiveness with both conventional and newer high technology materials. Research in materials processing will depend greatly on developing reliable data, process models, and computer process simulation techniques to bring insight into the relationship between the physical and chemical properties of the material during processing and the functional or structural properties of the specific end-product material.

Acting under a broadened charter and influenced by these industrial trends, NIST's new role in advanced materials technologies is carried out through joint technical collaborations with industry which begin as early as possible in the R&D process. That is, industry and NIST researchers work together from the inception of the ideas up to the stage at which a technology is ripe for commercial applications. The research goal is not to create a new material or process, but to enable industry to do so more effectively. The following three programs are examples of such cooperative ventures:

1. NIST and the Automotive Composites Consortium (ACC) are working on a cooperative program to improve the processing of structural polymer composite materials. The ACC partnership of Chrysler Corporation, Ford Motor Company, and General Motors Corporation is aimed at developing the technology industry needs for processing reliable, cost-effective structural polymer composite materials. The ACC

was established in 1985 by the three auto producers to jointly conduct precompetitive research. The companies selected structural composites as the topic for their first cooperative effort.

The cooperative project focuses on composites made by resin transfer molding (RTM) and structural reaction injection molding (SRIM). Leading industry representatives at two NIST workshops held in recent years indicated RTM and SRIM molding as among the most important processing methods for the next 5 to 15 years. Consequently, new NIST programs on polymer composite processing were focussed on these methodologies. These new programs have enabled the establishment of a CRADA with the ACC. In cooperation with the ACC, NIST researchers will develop and use computer models for both processing methods to simulate the fabrication of a complex demonstration part made by the ACC using the latest processing and performance technologies. The demonstration part is the front end structural member of a discontinued model of the Ford Escort to be constructed primarily of composite materials.

Under the program, the partnership agreed to develop technologies in three areas: processing, materials properties, and crash energy management. Advances in these areas will be demonstrated in the fabrication of the sample part using RTM and SRIM processing.

The RTM and SRIM processes involve injecting resins into a mold that has been filled with fiber reinforcements. By combining plastic resins with glass fibers, very versatile,

lightweight, and high-strength materials can be made.

The challenge is to achieve the optimum flow of resin so that the mold is completely filled in minimum time and with minimum pressure while avoiding bubbles and voids. The NIST computer models are designed to predict flow patterns and pressures during RTM and SRIM processing. Information from the simulations will be used by the ACC to optimize processing conditions and to improve mold design.

This collaborative effort with the ACC offers NIST researchers an opportunity to compare model predictions with data from the fabrication of a real, complex part. The information also will be used to develop generic tools and procedures needed to establish RTM and SRIM processing as efficient routes for producing a variety of polymer composite parts. We anticipate that this generic information will be broadly applicable to industries other than automotive and are exploring further industrial interaction in the aerospace arena in particular.

2. In the late 1970's and early 1980's major advances in several technologies resulted in their convergence to form a new systems approach for materials processing. This approach known as intelligent processing of materials (IPM) can be used to control the evolution of microstructure in real-time in contrast to conventional materials processing where process variables such as temperature and pressure are automatically controlled to preselected values, but the microstructure may not be directly controlled. These advancing technologies include (1) nondestructive evaluation (NDE) sensors for determination of materials properties and microstructure; (2) physical and mathematical process models based on the maturing materials science

concepts of relating process variables to microstructure, and microstructure to performance; and (3) fast, inexpensive computer hardware and appropriate software, e.g., expert systems and artificial intelligence.

Rapidly solidified metal powders are very important to systems requiring advanced materials, since they provide the basis for alloys which exhibit, after consolidation, high strength-to-weight ratios, improved fracture toughness and fatigue resistance, unique magnetic properties, and high corrosion resistance. Examples of potential applications of rapidly solidified powder metallurgy include jet engine turbine disks and fan blades made by near-net-shape consolidation processing, high-temperature aluminum-alloy airframe structures made by rolling and extruding consolidated forms, and advanced magnetic materials.

When metal powders are produced by atomization of liquid metals, the microstructural characteristics of the solidified particles are directly related to the size of the particles. The unique benefits of rapid solidification may be attained only if the particles are solidified under extremely rapid cooling rates in the range of 10^3 to 10^6 K/s. Since cooling is usually proportional to particle size, it is necessary that the droplets be within a certain size range to obtain the desired refined microstructure. Currently, atomization is carried out without any provision for real-time sensing of particle sizes and size distributions or controls based on these quantities. Therefore, the optimum values for the processing parameters such as melt flow rate, temperature, atomizing gas pressure, nozzle geometry and, perhaps, ultrasonic fields are selected by trial-and-error using several batches of material. It is then necessary to manually sieve the

resultant powder to obtain the required particles size distribution. This is undesirable because approximately 50 percent of the powder is of the wrong size and must be recycled. In addition, this is undesirable because sieving and recycling introduce impurities into the metal powder that degrade the final product.

A research program on the intelligent processing of rapidly solidified metal powders was begun in 1987. The program, developed through workshops held at NIST, and involving a number of producer and user companies, focussed on the automated, real-time, control of the atomization and solidification of liquid metals to form powders. The industrial consortium working with NIST on the program included Crucible Materials Corporation, General Electric Company, and Hoeganoes. Subsequent to the successful conclusion of this program in 1990, a second consortium was formed which includes the Department of Energy (DOE), G.E., Crucible Materials, and Pratt and Whitney, the goal of which is to develop an integrated, rapidly-solidified-powder, system. It is significant that because of the generic nature of the research program, normally, competitive companies such as G.E., and Pratt and Whitney are able to work together to develop new technology.

The research at NIST is aimed at developing an integrated system of particle size sensors, a process model and fundamental understanding of the fluid dynamics of the liquid jet break-up processes that lead to droplet formation, and on-line computer decision making using expert systems and artificial intelligence.

A process model and a clearer understanding of the atomization process are being developed that relate process variables such as atomization die gas pressure, atomization chamber gas pressure, metal viscosity, and die geometry to the liquid metal stream disruption process and metal droplet size. The modeling effort is based on a broad range of laboratory studies utilizing high speed photography, Schlieren interferometry, laser holography, and other techniques. This experimental effort is being coupled with computational modeling of the fluid dynamics and is leading to a strategy for control of the process. In order to produce the desired understanding of these flow processes, the researchers studies gas-only flow, gas-water flow, and gas-molten metal flow.

The computer control system, based on artificial intelligence and collective learning, is currently being developed. The computer control system can also provide simulations of the atomization process. The operator, via the user interface, can plan and execute atomization runs, monitor process conditions during runs, and analyze process data subsequent to the runs. The intelligent control system is responsible for reconciling user requests with current process conditions in order to meet production objectives.

3. Since the early 1980s, NIST has been collaborating with the steel industry to develop process control sensors to improve productivity and product quality. In 1983, NIST and the American Iron and Steel Institute (AISI) established a joint research program which led to the successful development of two of these sensors, one for porosity detection and the other for measurement of temperature distribution. The research, conducted mainly in NIST laboratories, involved close day-to-day

collaboration between NIST scientists and staff from the steel industry assigned to NIST and supported by the AISI.

Looking to the future, NIST continues to interact with the metals industry through research planning activities and updates the technical content of the NIST program to reflect changes in research needs. Advanced manufacturing techniques increasingly demand materials of greater reliability and uniformity at competitive cost. Specific demands for properties and performance can be met by control of the processing of the materials from synthesis or raw material production to forming/finishing, i.e., by use of intelligent processing.

This NIST experience in intelligent processing of advanced materials is now being applied to advanced processing in the steel and aluminum industries. In 1989, NIST was invited to participate in an AISI-organized forum to identify the long-range research opportunities for the steel industry. The industry participants concluded that research opportunities could best be addressed in the context of three long-range development projects: direct production of liquid steel; near-net shape casting; and finishing and coating operations. Successful integration of these three contiguous unit operations would yield important benefits by responding to the increasing restraints on traditional batch processing, by developing new product properties to match customer needs, and by taking advantage of this era of computational plenty to control processes for increased efficiency and product quality. A decision was made to organize an industry-led workshop to highlight the recent advances in sensing, modeling, and process control, to identify areas of need in the primary metals industries and the role

of intelligent processing of materials concepts in solving these needs, and to develop a strategy for implementation of research results.

Planning for the workshop was initiated through a steering committee that I chaired, with representatives from steel, aluminum, and copper trade associations, individual companies, the academic community, and Federal agencies. The workshop, sponsored by NIST, DOE, and the AISI, was held in August 1989. Industry, university, and government participants reviewed information provided by researchers and operating staff from industry and developed a plan for coupling the advancing state of materials processing in the primary metals industries. The report of the workshop summarized a research agenda for the intelligent processing of steel by defining the key elements producers need for the intelligent processing of steel, assessing the status of available technologies, and outlining strategies for implementing their use.

The steel industry has already acted on the results from the workshop. An AISI advisory committee has reviewed the findings and has recommended to the AISI that priorities be determined from the research agenda and a long-term national research program be established with an industry consensus. NIST has taken an active role in this planning process and, at the request of the AISI, has submitted four proposals for inclusion in the national research program. These proposals are currently undergoing peer review for possible joint funding by AISI and DOE. One of these proposed projects is concerned with intelligent control of steel sheet texture during processing. Sheet texture (or metal grain orientation) is vitally important in controlling the quality of the subsequent formability of sheet steel by automotive companies and other

industries utilizing stamped sheet steel. The second proposed project is directed to measuring the height of molten materials in the next generation, direct steel making process. Knowing this height will be required to maintain control of very aggressive and hot chemical reactions. The third proposed project deals with the experimental validation of mathematical process models for intelligent control of the thermomechanical processing of steel sheet. This is important because of the potential to significantly reduce the number of processing stops. The final proposal is aimed at developing on-line sensing capability to measure the mechanical properties of steel sheet. Control of the mechanical properties is critical because the mechanical properties or strength of the steel directly affects product performance.

In FY 1991, NIST received budget initiative funding of $900,000 to expand upon our early efforts in intelligent processing of materials and to initiate a major program with industry in this area. As the central focus of this initiative, a number of projects were started in December 1990 in support of intelligent processing of steel. These projects include developing sensors for texture, liquid-solid interface position, grain size, and yield strength in steel during processing, and research on the scientific basis for process models. These projects are directly related to AISI plans and needs and are focused on providing part of the generic scientific basis needed for intelligent processing of steel.

Summary

The roles of Federal laboratories in technology transfer and in joining with industry in generic precompetitive research is still evolving. For NIST, with its unique role to provide appropriate support to industry, the experiences gained in this arena underscore the importance of two complementary factors in assuring NIST's successful interaction with industry. They are, first, the involvement of industry from the earliest planning stages of a program, through planning workshops and by having industry-sponsored research associates work hand-in-hand with NIST scientists and engineers; and second, long-range generic research laboratory programs at NIST must be maintained to support associated industrial research efforts.

Appendix: Additional NIST Programs in Materials Technology

NIST's role in developing materials technology is carried out through a number of avenues, including basic research, the operation of unique facilities, evaluated data dissemination, and standard reference materials:

Basic Research - Interaction with customers is primarily through the function of professional technical societies and archival publications. In 1990, the research staff of the Materials Science and Engineering Laboratory (MSEL) authored or coauthored 746 technical papers and presented 476 talks.

In 1984, NIST researchers discovered a new class of material structures that were neither uniformly ordered like crystals nor amorphous like glasses. These new materials, called quasicrystals, are not made up of repeated unit cells containing the same distribution of atoms. By contrast, these new materials exhibit orientational symmetry without translational symmetry. The first quasicrystals exhibited five-fold symmetry, forbidden in conventional, periodic crystals. Until the NIST discovery, it was believed that crystals could never have five-fold symmetry because a single unit cell that has five-fold symmetry, e.g. a dodecahedron, cannot be assembled to completely fill space. This discovery has challenged the field of condensed matter physics because the current understanding of the electronic, thermal, and mechanical properties of crystalline solids is based on periodic structures.

A widely recognized important recent contribution of our fundamental research activities has been the work on the phase equilibria and structure of the high T_c superconductors. The accuracy and timeliness of the work on the phase equilibria and structure measurements speeded the early stages of the investigations of the properties of these new materials. A number of major U.S. companies approached MSEL for collaborative efforts because of the recognized strengths in ceramic phase equilibria and phase diagrams and the unique capability of neutron scattering expertise at the NIST reactor to elicit the structure details. The archival publications of superconductor structure have been among the 100 most cited papers in the U.S. in recent years.

Unique Facilities - Customers have direct access for both collaborative and proprietary research, including such national user facilities as the NIST Research Reactor, Cold Neutron Research Facility, and Synchrotron X-Ray Beamlines.

Research Reactor and Cold Neutron Research Facility (CNRF) - The NIST Reactor (NBSR), one of the major research reactors in the United States, is a 20 MW reactor located at the Gaithersburg, MD site and contains 25 experimental facilities used for materials science, chemical analysis, nondestructive evaluation, neutron standards, and irradiations. The experimental facilities in the reactor hall are involved int he following activities: neutron scattering and diffraction, neutron radiography, chemical trace analysis by neutron activation and depth profiling, fundamental neutron physics, long-term irradiations, and isotope production.

As designed in the early 1960s, the reactor had a provision for a large volume cold neutron moderator built into it when constructed. Utilizing this capability, a major program has been initiated to develop a national facility for cold neutron research, the Cold Neutron Research Facility (CNRF). The advanced measurement technologies introduced by the CNRF have broad application in areas of basic and applied science that are directly relevant to advances in the materials communications, transportation, chemical, electronics, and biotechnology industries. The CNRF is based on the use of total reflection inside neutron "guides" that transport intense beams of neutrons allow determination of larger scale structures such as polymers, precipitates, biological molecules, and colloids, and allow easier study of optical effects, including interference, refraction and nuclear properties.

When fully completed in the mid 1990s, the CNRF will provide fifteen new experimental stations for use by U.S. researchers, with capabilities currently unavailable in this country. The instruments can be conveniently grouped into four categories: "Materials Structure (three small angle neutron scattering [SANS] instruments, reflectometer, grazing-incidence diffractometer), Materials Dynamics (triple-axis spectrometer, spin-polarized inelastic neutron spectrometer, time-of-flight spectrometer, back-reflection spectrometer, spin-echo spectrometer), Chemical Analysis (depth profiling facility, prompt-gamma facility), and Neutron Physics (neutron interferometer, fundamental physics station). Eight experimental stations will be operational by the close of 1991, with four additional instruments coming on-line by 1993. The CNRF will be operated as a National Facility open to all qualified researchers on the basis of scientific merit. One-third of the experimental stations will be developed and maintained by

organizations outside of NIST.

Other facilities at NIST include those for small angle x-ray scattering and for mechanical testing. The information on microstructure of materials obtained using the 10-meter Digital Small-Angle X-Ray Scattering Camera is important in characterizing materials such as films, fibers, and advanced engineering materials, and is used to improve the processes used for synthesizing and controlling the performance of these materials. Currently, eight industrial customers use it for proprietary research on polymeric materials. Other customers include other government laboratories and academic institutions, whose staff carry out research in collaboration with MSEL staff. The materials studied include polymer films used in consumer products, films used as electronic substrates and storage media, fibers used as yarns and textiles, polyelectrolytes for advanced energy storage systems, advanced engineering plastics for the auto industry, and specialty polymers used in coatings.

MSEL possesses unique facilities for large scale mechanical testing and evaluation of materials and components for cryogenic service that are used by a number of large corporations. The 1-million-pound-force capacity facility is the only one in the U.S. capable of performing these tests at low temperatures. For one company, large-scale tests on composite tubes at cryogenic temperatures were carried out that simulated the thermal and mechanical conditions anticipated for the support struts of a superconducting magnetic energy storage (SMES) device.

Evaluated Data - Marketing of compiled and evaluated data is largely carried out through agreements with materials societies and other materials data organizations.

In the Materials Structure Data Program, theory, algorithms, and computer programs have been developed to establish extensive networks of material inter-relationships within and between scientific data bases. Acta Crystallographica is now routinely searching these databases for each newly reported structure to assure that the determination is indeed new. It is estimated that as many as 10,000 independent crystal-structure searches per year are performed.

Since 1933, a collaborative effort with the American Ceramic Society (ACerS) has been directed towards the production of Phase Diagrams for Ceramists. These are the world's major compilations of evaluated phase equilibria data for non-alloy, inorganic systems on which the processing and temperature limits of performance of most ceramics are based. Eight volumes have been published to date, containing about 9000 diagrams. About $2.5 million was raised by ACerS from industrial and private sponsors for an expansion of this program.

The Corrosion Data Center is a joint program between NIST and the National Association of Corrosion Engineers (NACE). The Center serves as a focal point for the development of personal computer programs to facilitate widespread distribution of evaluated corrosion performance and control data for engineering materials exposed to a wide range of industrial environments. The annual cost of corrosion to the U.S. economy is estimated to be $230 billion per year cost and it is further estimated that

proper design and selection of materials could reduce this by as much as 15%, a potential saving in excess of $30 billion per year. To date, approximately 900 Corrosion Data Center outputs on materials selection and control of corrosion have been sold.

There are four additional material data centers located within MSEL: Alloy Phase Diagram Data (with ASM International); Tribology Data (with Actis, Inc.); Structural Ceramics Data (with Gas Research Institute); and Cryogenic Materials Data (with Department of Energy).

Standard Reference Materials - Coordinated through the NIST Office of Standard Reference Materials, new reference materials are developed when critical needs are identified by customers. Since 1986, almost 15,000 units of 203 different MSEL-developed standard reference materials have been sold.

The Charpy impact test is the most widely used American Society for Testing and Materials (ASTM) standard for predicting the behavior of steel used in structures and other products. Since 1989, responsibility for providing standards test materials and calibration services for the certification of impact test machines has been located in MSEL. Reference specimens for the certification of the test machines are sold to over 1,000 customers worldwide. Approximately 65% of these customers are U.S. industrial firms.

Over 50 different coating thickness standard reference materials are produced using electrodeposition techniques. This standard is used by instrument manufacturers and aerospace companies to calibrate thickness measuring instruments. Typical applications include the thickness of paint and other organic coatings on steel as well as the thickness of galvanized and other nonmagnetic metallic coatings. Sales are approximately $400 thousand per year, evidence of a significant industrial need.

Under the auspices of ASTM, six companies have provided funding for the development and production of a high temperature melt flow standard. This polypropylene standard reference material will be used to check the melt flow rate apparatus used in conjunction with an ASTM test method. This test method is widely used by both polymer resin producers and polymer resin users to determine the melt flow rates of polymer resins, an important parameter in the process control of polymers.

Mr. VALENTINE. Thank you.
Dr. Millburn?

STATEMENT OF DR. GEORGE MILLBURN, EXECUTIVE VICE PRESIDENT, NATIONAL CENTER FOR ADVANCED TECHNOLOGIES, WASHINGTON, D.C.

Dr. MILLBURN. Good morning, Mr. Chairman and members of the committee.

My name is George Millburn, and I am Executive Vice President of the National Center for Advanced Technologies. Today I represent the Center and will discuss our activities related to critical technologies and advanced materials.

As you probably know, the center was established to guide the development of the key technologies for the year 2000 by the Aerospace Industries Association. Two of the 11 key technologies are materials: advanced composites and advanced metallic structures. Materials also appear on other lists of key critical or emerging technologies.

The Advanced Composite Strategic Plan developed by the technology teams over the last two years gives detailed directions to ensure realization of the full potential of these remarkable materials. The plan focuses on building on the current industrial base the U.S. has already developed. It calls for a new era of cooperation between industry, government, and academia and a strong, coordinated, and focused program. It truly represents a national consensus, as more than 1,000 experts took part in its creation. The plan represents a volunteer effort with a total value estimated at $3 million, assuming the team could have been assembled under a different approach. About two-thirds of the effort came from industry.

Currently, the United States is even in this field or slightly ahead of our European competitors, and the Japanese are a little ahead in product introduction. Foreign companies are purchasing American companies in order to enhance their positions.

Our experience with composite materials is typical of the approach of the Center for Advanced Technologies. The Center differs from other groups working with technologies in going beyond lists and developing detailed, strategic technology development plans. In addition to the one on composites, we have published one on rocket propulsion and plan to have six more ready for publication later this year.

Perhaps the most unique attribute of our plans is that they are developed cooperatively by industry, Government, and academia. Industry takes the lead in the partnership of equals. All participants are welcome, and by the time the final plan is published, several hundred experts in the field have contributed in one way or another. No other strategic development technology plans have been prepared with this breadth of participation, which truly represents a national consensus.

Just stopping with lists of critical technologies is not sufficient. Publishing plans, although the next step, is still not sufficient. First the plans must be implemented, and even then the technologies must be demonstrated before entrepreneurs will risk developing new products. The net objective of all our efforts is to enable

industry to produce world class products which are competitive in the global marketplace.

We lead the world in developing technologies, and no other nation approaches the United States in its overall breadth and depth of technological competence and innovation, but we no longer lead in applying new technology to commercial products. Hence, we are slowly losing the competitive dominance we once enjoyed in global markets. It is essential to our economic well-being and security that we regain some of the competitive advantage we have permitted to slip away. Technology is only one part of this effort, but certainly an essential and primary one.

The aerospace industry has the greatest positive trade balance of any U.S. manufacturing industry. Our efforts are meant to protect and even extend that edge. The efforts of the National Center for Advanced Technologies and Aerospace Industries Association are not unique to the aerospace industry. We believe they can be extended to many other industries, and we stand ready to assist in transferring our process and strategy to others who are willing to share this challenge with us.

Thank you, Mr. Chairman.

[The prepared statement of Dr. Millburn follows:]

TESTIMONY OF GEORGE P. MILLBURN

ON BEHALF OF

AEROSPACE INDUSTRIES ASSOCIATION OF AMERICA, INC.

AND

THE NATIONAL CENTER FOR ADVANCED TECHNOLOGIES, INC.

BEFORE THE

UNITED STATES HOUSE OF REPRESENTATIVES

SUBCOMMITTEE ON TECHNOLOGY AND COMPETITIVENESS

June 11, 1991

MR. CHAIRMAN AND MEMBERS OF THE SUBCOMMITTEE:

MY NAME IS GEORGE MILLBURN. I AM EXECUTIVE VICE PRESIDENT OF THE NATIONAL CENTER FOR ADVANCED TECHNOLOGIES. TODAY I AM REPRESENTING THE NATIONAL CENTER FOR ADVANCED TECHNOLOGIES (NCAT)

THE AEROSPACE INDUSTRY IS GREATLY CONCERNED ABOUT THE U.S. TECHNOLOGY BASE AND THE INDUSTRY'S FUTURE GLOBAL COMPETITIVENESS. AS A RESULT, IN 1987 AIA INITIATED A NATIONAL COOPERATIVE EFFORT AMONG INDUSTRY, GOVERNMENT AND ACADEMIA CALLED "KEY TECHNOLOGIES FOR THE YEAR 2000". THESE ELEVEN KEY TECHNOLOGIES, WHEN DEVELOPED AT AN ACCELERATED RATE, WILL PROVIDE A STRONGER, HEALTHIER TECHNOLOGY BASE, ALLOWING THE AEROSPACE INDUSTRY TO REMAIN A MAJOR COMPETITOR IN THE WORLD MARKETPLACE.

WE HAVE ESTABLISHED AN IMPLEMENTATION FRAMEWORK FOR THE PROGRAM:

1) THERE IS A BOTTOM-UP VIEW FROM TECHNOLOGY TEAMS, WITH BROAD PARTICIPATION BY INDUSTRY, GOVERNMENT AND UNIVERSITY EXPERTS. THEY ARE DEVELOPING ROADMAPS FOR THE KEY TECHNOLOGIES AND MAKING RECOMMENDATIONS REGARDING THE DIRECTION OF NATIONAL TECHNOLOGY DEVELOPMENT PLANS.

2) THERE IS A TOP-DOWN VIEW FROM THE AEROSPACE TECHNOLOGY POLICY FORUM, WHICH CONSISTS OF HIGH-LEVEL POLICY LEADERS IN INDUSTRY, GOVERNMENT AND ACADEMIA. THE FORUM ALSO FACILITATES COOPERATION IN THE IMPLEMENTATION OF NATIONAL TECHNOLOGY POLICY.

3) THERE IS A COORDINATED VIEW FROM THE NATIONAL CENTER FOR ADVANCED TECHNOLOGIES (NCAT), A FOUNDATION SPONSORED BY THE AEROSPACE INDUSTRIES ASSOCIATION (AIA). NCAT COORDINATES THE KEY TECHNOLOGIES DAILY OPERATIONS, AND LEADS THE INTEGRATION EFFORT.

ADVANCED COMPOSITES WAS IDENTIFIED AS KEY BECAUSE OF ITS HIGH LEVERAGE, POTENTIAL FOR COMMERCIAL AND MILITARY APPLICATIONS, AND, AS AN ENABLING TECHNOLOGY ALLOWING CAPABILITIES FAR BEYOND CONVENTIONAL MATERIALS.

THE TERM "COMPOSITES" REFERS TO A FAMILY OF MATERIALS MADE UP OF REINFORCEMENTS EMBEDDED IN DIFFERENT HOST OR MATRIX MATERIALS. RECENTLY DEVELOPED COMPOSITE MATERIALS HAVE IMPROVED TWO-FOLD IN STRENGTH. THESE IMPROVEMENTS RESULTED FROM RESEARCH PERFORMED OVER THE LAST QUARTER CENTURY BY INDUSTRY, GOVERNMENT AND UNIVERSITY LABORATORIES. THE VAST ARRAY OF APPLICATIONS FOR COMPOSITES HAS INCREASED BECAUSE THEY CAN BE MADE STRONGER AND

MORE CORROSION RESISTANT THAN STEEL, LIGHTER THAN ALUMINUM, EXTREMELY STIFF OR PREDICTABLY COMPLIANT, TOUGH, AND HEAT RESISTANT. NOT ONLY ARE COMPOSITES AN ENABLING TECHNOLOGY FOR AEROSPACE APPLICATIONS, BUT THEY ARE ALSO VITAL TO THE PRODUCTION OF AUTOMOBILE COMPONENTS, BIOMEDICAL PRODUCTS, AND SPORTING GOODS.

ADVANCED COMPOSITES ARE OF CRITICAL IMPORTANCE TO THE AEROSPACE INDUSTRY BECAUSE THEY ARE VITAL TO SYSTEM APPLICATIONS AND REQUIREMENTS. CONTINUED DEVELOPMENT OF HIGH STIFFNESS, GREATER STRENGTH, AND TOUGHER COMPOSITES ARE REQUIRED FOR EMERGING GENERATIONS OF BOTH COMMERCIAL AND MILITARY AIRCRAFT AND SPACECRAFT. COMPOSITES ARE AN ENABLING TECHNOLOGY FOR SOME OF THE NEWEST CONCEPTS WHICH ARE BOTH ECONOMICALLY AND STRATEGICALLY IMPORTANT TO THE U.S. - THE NATIONAL AEROSPACE PLANE BEING A PRIME EXAMPLE. IN HIGH TEMPERATURE APPLICATIONS, DEVELOPMENT OF NEW ENGINES CAN POTENTIALLY RESULT IN DOUBLE THE THRUST WITH FORTY PERCENT LESS FUEL CONSUMPTION.

NCAT COORDINATED EFFORTS BY AIA MEMBERS, GOVERNMENT, AND UNIVERSITIES TO DEVELOP A ROADMAP AND THEN A DETAILED STRATEGIC TECHNOLOGY DEVELOPMENT PLAN FOR COMPOSITE MATERIALS. ABOUT ONE HUNDRED AND FIFTY EXPERTS IN THE FIELD CONTRIBUTED TO THE PLAN, AND SEVERAL HUNDRED REVIEWED IT. NCAT AND AIAA (AMERICAN INSTITUTE OF

AERONAUTICS AND ASTRONAUTICS) SPONSORED A NATIONAL SYMPOSIUM LAST DECEMBER TO INTRODUCE THE DRAFT PLAN TO THE ENTIRE COMMUNITY. APPROXIMATELY TWO HUNDRED AND FIFTY INDUSTRY, GOVERNMENT AND ACADEMIA MEMBERS ATTENDED THE SYMPOSIUM COMMENTS RECEIVED WERE INCORPORATED INTO A REVISED PLAN WHICH WILL BE PUBLISHED IN THE NEAR FUTURE. DISTRIBUTION OF THE PLAN IS LIMITED TO U.S. CITIZENS BY THE INTERNATIONAL TRAFFIC IN ARMS REGULATION (ITAR).

THE AIA ADVANCED COMPOSITES STRATEGIC PLAN IS BEING USED BY DOD IN THEIR CRITICAL TECHNOLOGIES EFFORT. IT HAS ALSO BEEN CIRCULATED THROUGHOUT THE MATERIALS COMMUNITY FOR COMMENT. IT IS EXPECTED THAT MORE THAN 1000 "MOVERS & SHAKERS" IN THE MATERIALS AND STRUCTURES COMMUNITY WILL HAVE PARTICIPATED IN THE DOCUMENT DEVELOPMENT.

FOREIGN COMPETITION IN THE FIELD OF COMPOSITE MATERIALS CONTINUES TO INCREASE. JAPAN AND THE EUROPEAN COMMUNITY HAVE ALREADY SHOWN INCREASES IN MARKET SHARE IN MATERIALS AND HARDWARE. THE U.S. CAN NO LONGER PROCRASTINATE. ACCORDING TO A 1990 NATIONAL RESEARCH COUNCIL REPORT, THE UNITED STATES IS ALREADY LAGGING IN APPLYING ADVANCED MATERIALS TO MANUFACTURING PROCESSES. EVIDENCE OF FURTHER EROSION IN THE MATERIALS FIELD IS THE INCREASING DEPENDENCE OF U.S. MANUFACTURERS ON FOREIGN SUPPLIERS FOR RAW MATERIALS NEEDED FOR MANY COMPOSITES.

AIA/NCAT IS COMMITTED TO THE ESTABLISHMENT OF A NATIONAL EFFORT IN ADVANCED COMPOSITES BASED ON THE PRINCIPLES OF COOPERATION AND CONSENSUS. IT IS OUR BELIEF THAT THE NATION MUST PLAN FOR THE FUTURE AS OUR INDUSTRY'S ROLE CONTINUES TO EXPAND IN THE INTERNATIONAL MARKETPLACE.

WE AT NCAT VIEW THE DEVELOPMENT OF A NATIONAL COMPOSITES PLAN AS A VITAL PART OF THE KEY TECHNOLOGIES EFFORT. WE THINK IT WILL HELP STRENGTHEN THE NATION'S TECHNOLOGY BASE. ALONG WITH CONSORTIA, SUCH AS THE NASP MATERIALS EFFORT, THE COMPOSITE MATERIALS CHARACTERIZATION CONSORTIUM, AND THE OFFICE OF SCIENCE AND TECHNOLOGY POLICY (OSTP) EFFORT TO STRENGTHEN MATERIALS SCIENCE AND ENGINEERING; OUR PLAN WILL PROVIDE THE BASIS FOR MUCH IMPROVED, HIGH-PERFORMANCE STRUCTURES AND SYSTEMS MANUFACTURED AT LOWER COST AND OF HIGHER QUALITY THAN ANY IN THE WORLD. U.S. AEROSPACE PRODUCTS WILL NOT ONLY BE COMPETITIVE, BUT PREEMINENT, IN THE GLOBAL MARKETPLACE.

COMPOSITES, HOWEVER, ARE NOT THE ONLY MATERIALS THAT THE U.S. MUST BE CONCERNED ABOUT. AIA/NCAT HAS RECENTLY ADDED ADVANCED METALLIC STRUCTURES TO ITS LIST OF KEY TECHNOLOGIES WITH THE PROVISO THAT ITS ROADMAP AND PLAN BE MERGED WITH THAT OF ADVANCED

COMPOSITES TO GIVE AN AEROSPACE VIEW OF "ADVANCED MATERIALS & STRUCTURES".

THIS VIEW IS PROPER BECAUSE MATERIALS ARE "DRIVERS" FOR AEROSPACE SYSTEMS ACROSS THE SPECTRUM OF USE FROM THE VOYAGER AROUND-THE-WORLD-AIRCRAFT, TO THE B-2 STEALTH BOMBER, THE NATIONAL AEROSPACE PLANE, (AND ALSO THE M-1 TANK AND SUBMARINES). THESE ARE OBVIOUSLY HIGH-PERFORMANCE MATERIALS USED IN STRUCTURAL APPLICATIONS. THE KEY TO SUCCESS IS THEIR USE IN A COMPETITIVE PRODUCT.

THE NASP MATERIALS CONSORTIUM IS WORKING WELL, BUT MATERIALS MUST BE PROCESSED AND SHOULD BE CONSIDERED AS STRUCTURES. COMPOSITES MUST BE THOUGHT OF IN TERMS OF STRUCTURES. THEY ARE "DESIGNER MATERIALS" CONSISTING OF FIBERS AND MATRIX AND SOME COHESIVE FORCE HOLDING THE FIBER AND MATRIX TOGETHER. THEY MUST BE PROCESSED/MANUFACTURED INTO A FINAL PRODUCT.

IN THE AIR-BREATHING PROPULSION PROGRAM IT IS ESTIMATED THAT BY THE YEAR 2010 COMPOSITES WILL MAKE UP 50% OF THE ENGINE WEIGHT. THIS, IN A SENSE, IS STARTING A NEW INDUSTRY FOR HIGH TEMPERATURE ENGINE MATERIALS AND STRUCTURES. IT WILL ADMITTEDLY BE A NICHE MARKET, BUT A VERY IMPORTANT ONE NONETHELESS. IN THIS SENSE WE

ARE CREATING NEW PRODUCTS FOR THE GLOBAL MARKET, MATERIALS BEING THE CENTERPIECE OF THAT EFFORT.

IN CLOSING I WOULD LIKE TO STATE THAT WE AT NCAT SEE A NEED TO PROTECT THE NATIONAL TECHNOLOGY BASE. AS DOD FUNDING GOES DOWN THERE WILL BE A NATURAL TENDENCY TO REDUCE THE SCIENCE AND TECHNOLOGY EFFORT AS WELL. IN TURN, AS INDUSTRY SALES TO DOD GO DOWN, INDUSTRY IR&D WILL BE REDUCED, THE RESULT BEING THE TECHNOLOGY BASE FACES A CONSIDERABLE REDUCTION. GOVERNMENT NEEDS TO SUPPORT THE TECHNOLOGY BASE IN ITS ENTIRETY AND MAINTAIN A CONSISTENT AND CONSTANT LEVEL OF FUNDING. THIS IS A PROBLEM FOR INDUSTRY AND GOVERNMENT TO TACKLE TOGETHER. CURRENTLY, THE GOVERNMENT IS FUNDING BASIC RESEARCH AND GENERIC TECHNOLOGIES, BUT TECHNOLOGY SHOULD BE VALIDATED BEFORE IT IS PUT TO USE. SOME FORM OF DEMONSTRATION IS NEEDED, ESPECIALLY WHERE TWO SOMEWHAT SYNERGISTIC TECHNOLOGIES ARE USED FOR THE FIRST TIME. INCREASING THE NUMBER OF DEMONSTRATIONS OF THIS TYPE COULD REDUCE THE TIME FROM IDEA TO APPLICATION.

MR. CHAIRMAN, I THANK YOU FOR THE OPPORTUNITY TO APPEAR BEFORE THIS SUBCOMMITTEE TODAY AND I AM PREPARED TO RESPOND TO ANY QUESTIONS.

Mr. VALENTINE. Thank you.
Mr. Reed?

STATEMENT OF WILLIAM REED, PRESIDENT, SEMICONDUCTOR EQUIPMENT AND MATERIALS INSTITUTE, MOUNTAIN VIEW, CALIFORNIA; ACCOMPANIED BY: JERRY CODER, VICE PRESIDENT, KTI CHEMICALS, INC.

Mr. REED. Good morning, Mr. Valentine, Mr. Lewis, and members of the committee.

I want to talk to you a little bit this morning about materials and chemicals used in the semiconductor industry. I've brought along a little help—Mr. Jerry Coder, who is Vice President of KTI Chemicals, which is a division of Union Carbide, who will talk a little bit about the chemicals end. I'll stick primarily to the materials.

As you know, the semiconductor industry is really an industry in change caused by a market shift from the United States to Asia and by intense global competition. I represent the Semiconductor Equipment and Materials Institute, which is a trade association serving a $20 billion capital equipment and materials market. Our members primarily manufacture tools, materials, and services to the worldwide semiconductor industry. In the United States, SEMI represents over 850 small- to medium-size firms who are located in 39 States and whose annual gross revenues are approximately $8 billion, of which they invest about $2 billion in research and development.

Eighty-five percent of our members are really small businesses with sales of $50 million or less, yet an increasing amount of their sales have to be generated through export as the market moves offshore. Our members are confronted with an export-or-die dilemma. Export sales and distribution systems are very costly and difficult to build.

We've been asked to comment on the status of the electronics materials industry in the United States and to make recommendations to ensure the industry's continued viability. This is a very broad undertaking, as the market includes silicon, gallium arsenide, quartz, photoresist, etchants, strippers, processing gases, chemicals, dopants, sputtering materials, and I could go on and on. For the purpose of today's discussion, however, we'll concentrate on substrates and some major chemicals used in semiconductor processing.

At the outset, it's important to understand the characteristics of semiconductor materials. Semiconductor materials are high-technology products requiring unique, exacting specifications. For the most commonly used materials, including silicon, photoresist, wet chemicals, gases, there is an abundance of suppliers. For example, there are 14 silicon suppliers and 16 photoresist manufacturers on a worldwide basis. However, we're undergoing changing market conditions here in the United States.

In the past decade, U.S. market share of the worldwide semiconductor market has declined from 60 percent to 40 percent. As a result, the suppliers to this market are compelled to look overseas to sell, a strategy which increases operating costs. The largest

outlet for U.S. equipment and materials suppliers is Japan, a most difficult market for even the most sophisticated of U.S. manufacturers. However, demand is ever-increasing for semi-conductor products.

A brief history—and I'll make this very brief—of the silicon industry in the United States illustrates the effect of a market moving offshore. The semiconductor industry was formed in the United States in the 1950s and 1960s and was served by major U.S. chemical companies. At one time, DuPont, Merck, Dow-Corning, Union Carbide, Mallinckrodt, Monsanto, and W.R. Grace were supplying silicon to this market. Who could create a more prestigious list of well-funded, technically astute U.S. corporations?

Today, however, there is not one major, world class silicon supplier which is U.S.-owned. The need to reinvest increasing amounts of capital in the fast-moving, ever-changing high technology business has hastened the exit of these companies from the silicon industry. So, too, did the migration of the customer base from North America to Asia. Additionally, the financial demands of research and development activities were such that the normal anticipated profits never materialized, which caused these companies to move on to higher-margin products.

Is this cause for immediate despair? SEMI believes not, since 35 percent of the silicon used on the world market is produced in the United States. In fact, the U.S. at the moment is a net exporter of silicon. However, the long-term outlook is quite uncertain.

MEMC, which is a German company which bought out a Monsanto plant, provides an excellent example of the current state of the U.S. silicon industry. This company, previously owned by Monsanto, is now owned by the German company, Huels. Huels purchased Monsanto after a two-year search to find a U.S. buyer proved unsuccessful. However, since that time, operations at MEMC have expanded, with new investments in plants and equipment totaling $80 million. This is in a two-year period. R&D activities remain in St. Peters, Missouri, managed by the U.S. president and the U.S. Board of Directors.

Fortunately, foreign ownership of silicon suppliers to the electronic industry has been a financial boost for the former U.S. companies. The change in industry ownership, however, underscores the volatility of the electronic materials industry. U.S. companies are increasingly reluctant to invest in high-technology operations because of the poor returns on these investments. A more favorable climate needs to be created to keep U.S. technology at a world class level and to assure a domestic customer base and domestic supplier base.

If we take a look at another important substrate, gallium arsenide, the same trend exists. All important research work initially was done in the United States, and virtually all manufacturing of the product was initially done here. Over time, these functions have moved to Japan, with one notable exception. Hewlett-Packard is rated as one of the top five producers of gallium arsenide material in the world, as well as one of the top five producers of the gallium arsenide devices themselves. They do not, however, produce gallium arsenide for the commercial market. Everything is used internally.

Another important materials application is ceramic packaging, which is used to house critical application integrated circuits. More than 90 percent of this production is controlled by non-U.S. companies, and interestingly enough, the Department of Defense is one of the largest consumers of ceramic packages.

I'm going to just move on to some recommendations, and then I'd like Jerry Coder to take on the chemicals part of the discussion.

In thinking about what needs to be done, it is SEMI's recommendation that a comprehensive study be initiated to assess the materials and chemical industries status and make recommendations as to priorities for action. The Semiconductor Research Corporation could be a candidate to conduct this study. And we suggest that the National Laboratories be enlisted and/or NIST in a materials-centered R&D effort in partnership with industry to support the recommendations originating in the study.

We need to make permanent and to expand the R&D tax credit. If funding becomes available, priorities should be given to those areas where the United States is deficient, such as in ceramics, quartz, and compound semiconductor materials. Congress should provide for an investment tax credit. U.S. manufacturers are and will remain reluctant to make these capital improvements unless there is an adequate return on their investments.

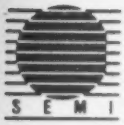
For example, an economically feasible silicon plant of 16 million square inches requires an investment of $125 million just for plant and equipment. That's got nothing to do with working capital and all the other things you need to make a silicon plant run.

Cumbersome government regulations need to be overhauled. These include overburdensome export controls, outdated antitrust guidelines, and some product liability statutes. NIST should be funded to provide support for the chemical and gases industry by providing facilities and technology to measure micro impurities in the semiconductor materials.

I'd now like to turn it over to Jerry Coder for a discussion of one element of the chemicals industry.

[The prepared statement of Mr. Reed follows:]

Semiconductor Equipment
and Materials International



Statement of

William H. Reed, President

Semiconductor Equipment and Materials International

and

J.P. Coder, Vice-President

KTI Chemicals

before the

U. S. House of Representatives

Committee on Science, Space and Technology

Subcommittee on Technology and Competitiveness

June 11, 1991

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Introduction

Semiconductor Equipment and Materials International is a trade association serving a $20 billion capital equipment and materials market. Our members provide manufacturing tools, materials and services to the worldwide semiconductor industry.[1] In the United States, SEMI represents over 850 small-to-medium size firms, who are located in 39 states and whose annual gross revenues are approximately $8 billion.[2] Over 85% of SEMI members have annual sales of $50 million or less. Yet, an increasing amount of their sales are generated through export orders.[3] As the market moves offshore, our members are confronted with an "export or die" dilemma. Export sales and distribution systems are costly and difficult to build.

SEMI has been asked to comment on the status of the electronic materials industry in the United States, and to make recommendations to ensure the industry's continued viability. This is a very broad undertaking, as the market includes silicon, gallium arsenide, quartz, photoresist, etchants and strippers, processing gases and chemicals, dopants, sputtering materials, encapsulating plastics and resins, ceramics, and metals such as gold and copper. For the purpose of today's discussion, we will concentrate on substrates and the major chemicals used in semiconductor processing.

At the outset, it is important to understand several unique characteristics of semiconductor materials. These characteristics include:

High Technology Products

- Semiconductor materials are high technology products because they are unique, with exacting customer specifications. The business requires extensive research and development activities, combined with significant after sales support.[4]

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[1] Attachment A

[2] Attachment B

[3] Attachments C&D

[4] The photoresist development cycle, for example is 2 years of R&D, and then three years to build sales volume. Thus, from the time the product characteristics are defined until significant income is generated could be as much as 5 years - for a worldwide market of $250M.

- **Competitive Pricing**

  For the most commonly used materials, including silicon, photoresists, wet chemicals, gases and deposition materials, there are an abundance of suppliers. For example, there are 14 silicon suppliers and 16 photoresist manufacturers worldwide.[5] This number of suppliers ensures constant price competition.

- **Changing Market Conditions**

  In the past decade U.S. market share of the worldwide semiconductor market has declined from >60% to <40%. As a result, U.S. suppliers to this market are compelled to look at overseas markets in order to grow their businesses, a strategy which increases operating costs. The largest outlet for U.S. equipment and materials suppliers is Japan, a difficult market for even the most sophisticated U.S. manufacturers.

- **Long Term Growth is Forecast for the Industry**

  Demand for faster, more powerful integrated circuits remains unabated. Moreover, there is a diffusion of these products into new markets, such as automobile electronics. It follows, therefore, that there are tremendous growth opportunities in the electronic materials business.[6]

Silicon, Gallium Arsenide and Ceramics

A brief history of the silicon industry in the U.S. illustrates the effects of a market moving offshore. The semiconductor industry was founded in the United States in the 1950's - 60's and was served by major U.S. chemical companies. At one time, DuPont, Merck, Dow Corning, Union Carbide, Mallinckrodt, Monsanto and W.R. Grace were supplying silicon to the market. Who could create a more prestigious list of well-funded, technically astute U.S. corporations? Today, however, there is not one major world class silicon supplier which is U.S. owned.

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[5] Attachment E

[6] Attachments F,G,H,I

The need to re-invest increasing amounts of capital in a fast-moving, ever-changing high technology business hastened the exit of these companies from the silicon industry. So too, did the migration of the customer base from North America to Asia. Additionally, the financial demands of the research and development activities were such that normal, anticipated profits never materialized, which caused the companies to move on to higher margin products. Is this a cause for immediate despair? SEMI believes not, since 35% of the silicon used on the world market is produced in the United States. In fact, the U.S. is a net exporter of silicon. However, the long term outlook is quite uncertain.

MEMC provides an excellent example of the current state of the U.S. silicon industry. This silicon company, previously owned by Monsanto, is now owned by the German chemical company Huels AG. Huels purchased Monsanto after a two year effort to find a U.S. buyer proved unsuccessful. Since that time the silicon operations of MEMC have expanded, with new investments in plants and equipment totalling $80 million. R&D activities remain in St. Peters, Missouri managed by a U.S. president and a U.S. board of directors. Similar stories can be told about the other European and Japanese-owned silicon plants in the U.S.

Fortunately, foreign ownership of silicon suppliers to the electronics industry has been a financial boost for the former U.S. companies. This change in industry ownership, however, underscores the volatility of the electronic materials industry. U.S. companies are increasingly reluctant to invest in high technology operations because of poor returns on these investments. A more favorable climate needs to be created to keep U.S. technology at a world-class level and to assure a domestic customer base and supplier base.

If we take a look at another important substrate, gallium arsenide (a compound semiconductor), the same trend exists. All the important research work was done in the United States and virtually all manufacturing of this product was initially done here. Over time, these functions have moved to Japan, with one notable exception. Hewlett-Packard is rated as one of the top five producers of gallium arsenide material in the world, as well as one of the top five producers of gallium arsenide devices. They do not, however, produce gallium arsenide for the commercial market--everything is used internally.

Another important materials application is ceramic packaging, which is used to house critical application integrated circuits. More than 90% of this production is controlled by non-U.S. companies. Interestingly, the Department of Defense is one of the largest consumers of ceramic packages.

One issue that stands out from the discussion of electronic materials is that there is not one central organization which is concerned about the state of the industry and the future for new materials and compounds. SEMATECH's primary concern is with manufacturing processes and process equipment. Its materials-related efforts have been helpful, but limited. With the work it is already undertaking, SEMATECH is not the venue for a materials centered effort. It would seem that the National Labs could be a starting point for a materials effort in the United States, in cooperation with interested U.S. commercial partners.

Chemicals and Gases

There are three critical challenges confronting the U.S. suppliers of semiconductor chemicals. These issues are tougher, customer-imposed specifications; vendor/customer responsibility for chemical use, distribution and retrieval; and the drive towards globalization. The inability to meet successfully any one of these challenges could mean the loss of market position and a rapid exit from the semiconductor materials industry.

The wonder of the microcircuit is its ability to concentrate more power into smaller, more dense areas. This is achieved by reducing the linewidths of the circuits, a process in which chemistry plays a critical role. Purity levels of the gases and chemicals must be extraordinarily high, reaching to a point where impurities are measured in parts per billion! A useful analogy would be like finding the one red brick in a white brick fence stretching from Washington to Boston.

Specifications these exact place a severe strain on companies who must purchase expensive analytical tools and services in order to demonstrate compliance with customer requirements. Additionally, these materials must work with a plethora of processing tools, which can often mean the purchase of these tools solely for demonstration and bench-marking purposes.

For example, the key piece of photolithographic processing gear is a wafer stepper. Photoresist manufacturers must qualify their products on these tools, which can cost in excess of $1.5 million each, with a new generation every two-three years.

Ownership of chemicals, especially those of a toxic nature, is a new feature of the supplier-customer relationship. Previously, a chemical company sold its products to a customer, who was responsible for the use, reclamation and disposal of the product.

With the advent of tougher product liability laws and with the imposition of Superfund legislation and regulations, customers are shifting ownership back to the supplier. SEMI member companies must now develop techniques to produce the chemicals, and also regulate their dispersal through the manufacturing environment. At the end of the fabrication cycle, they are responsible for reclaiming the chemical and a safe disposal. Again, this places an additional expense on company operations.

Finally, the issue of domestic and global partnering must be addressed by each company in this segment of our industry. It is no secret that semiconductor companies, in their drive to reduce operating costs, are reducing their list of qualified suppliers. Ideally, semiconductor manufacturers would like to replicate their domestic fabrication and assembly facilities in each new market they enter. This would reduce the period of time necessary to bring up a new facility by ensuring a level of reliability across all process steps.

In order to remain the supplier of choice, U.S. firms must establish partnerships with companies in Europe and Asia. In the past there has been an almost adversarial relationship between customer and vendor in the U.S. This has certainly improved recently - an important by-product of SEMATECH - but much more needs to be done to strengthen the bond between customer and supplier. The exchange of technology between these two is invaluable for the progress of the U.S. semiconductor industry.

SEMI's Recommendations

- Initiate a comprehensive government study to assess the materials and chemical industry's status and make recommendations as to priorities for action. The Semiconductor Research Corporation (SRC) could be a candidate to conduct the study.

- Enlist the National Laboratories and/or NIST in a materials-centered R&D effort in partnership with industry to support recommendations originating in the study.

- Make permanent and expand the R&D tax credit.

- If funding becomes available, priorities should be given to those areas where the United States is deficient, such as ceramics, quarts, and compound semiconductor materials.

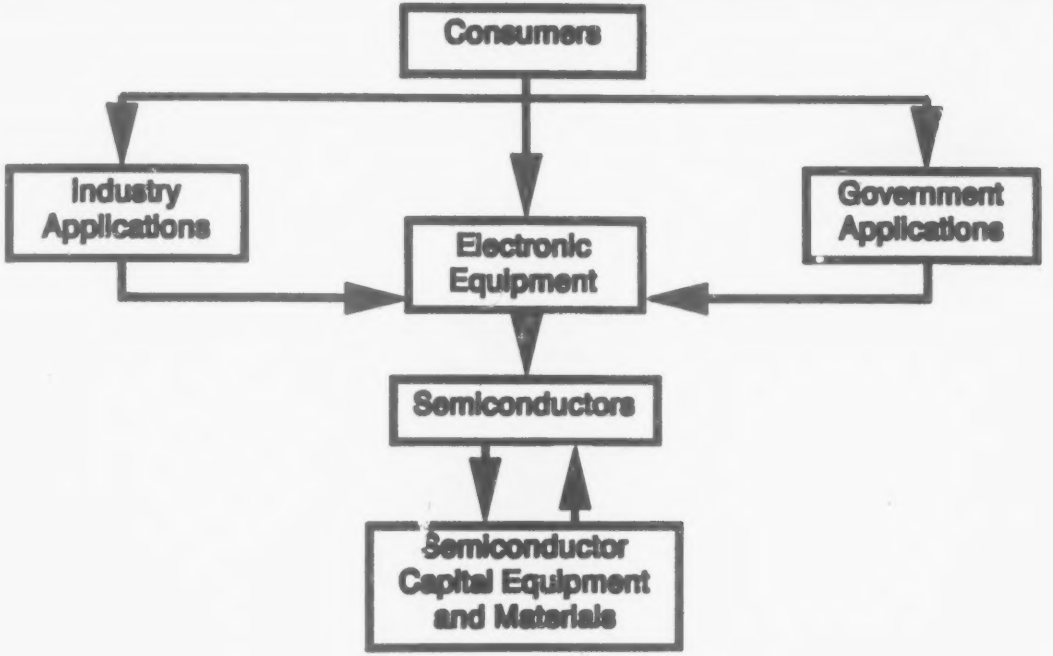
- The Congress should re-visit the concept of an investment tax credit. It takes expensive machinery and analytical instruments to produce Very Large Scale Integration (VLSI) grade products. U.S. manufacturers are, and will remain, reluctant to make these capital improvements unless there is an adequate return on their investments.

- Cumbersome government regulations need to be overhauled. These include overburdensome export controls, outdated antitrust guidelines, and some product liability statutes.

- NIST should be funded to provide support to the chemicals and gases industries by providing facilities and technology to measure micro-impurities in semiconductor materials. The ever-escalating cost of the equipment and technology needed to conduct this work makes it impractical for the average supplier to the industry, based on the financial return the company could expect to receive.

# # #

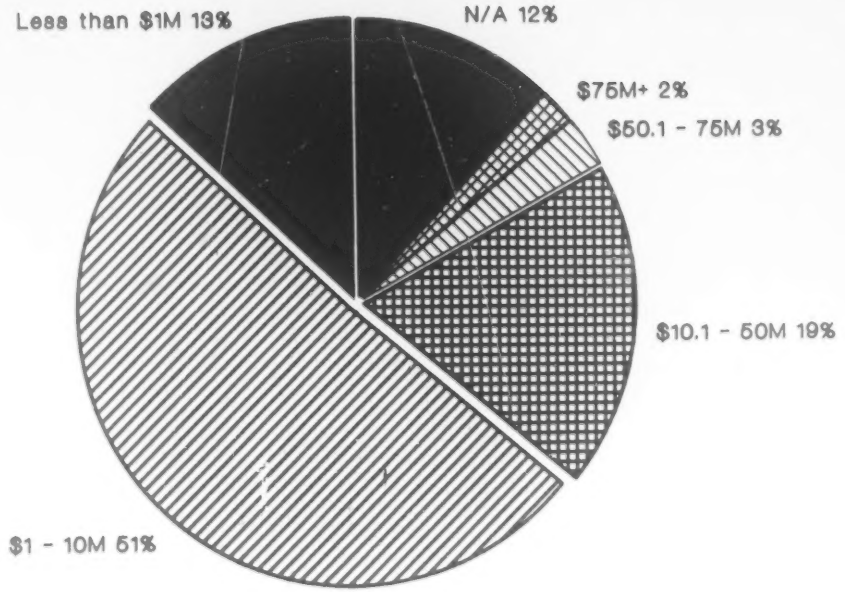
Electronics Industry Demand Flow



ATTACHMENT A

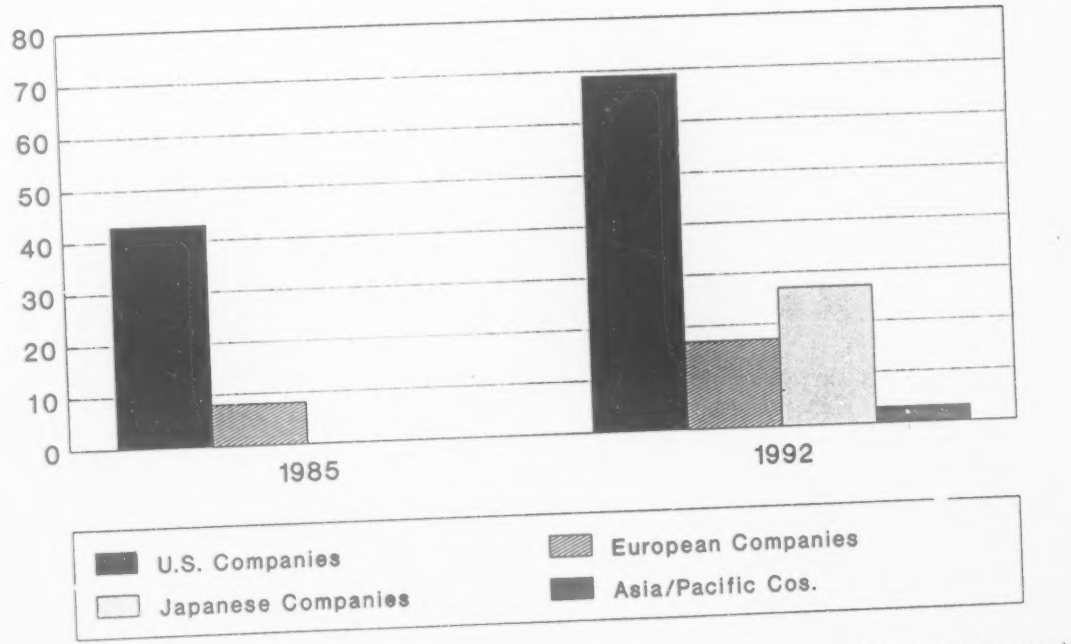
SEM INDUSTRY IN THE U.S.
850 Companies – 39 States

MEMBERSHIP ANALYSIS
By Annual Sales - 1989



ATTACHMENT C

SEMICONDUCTOR MANUFACTURERS
Overseas Fab Lines



Source: Dataquest

ATTACHMENT D

Silicon and Photoresist Suppliers

Silicon Suppliers

Shin-Etsu Handotai (Japan)
Huels AG (Germany)*
Osaka Titanium (Japan)
Mitsubishi Metals Corp. (Japan)**
Komatsu Electronic Metals (Japan)
Wacker (Germany)
Toshiba Ceramics (Japan)
Crysteco (U.S.)
Epitaxy, Inc. (U.S.)
Recticon (U.S.)
UniSil (U.S.)
Topsil Semiconductor Materials (Europe)
Korsil (So. Korea)
Lucky Advanced Materials (So. Korea)

Photoresist Suppliers

Ciba Giegy (Switzerland)
Hoechst (Germany)
Japan Synthetic Rubber (Japan)
Nagase & Co. (Japan)
Shipley (U.S.)
Tokyo Ohka Kogyo (Japan)
Hitachi (Japan)
Mitsubishi Kasei (Japan)
EKC (U.S.)
Nippon Zeon (Japan)
Shin Etsu (Japan)
Sumitomo Kagaku (Japan)
Tosoh (Japan)
Toyo Soda (Japan)
Olin Hunt (U.S.)
KTI (U.S.)
Dynachem (U.S.)

* Includes Monsanto Electronic Materials Corp. and Dynamit Nobel Silicon

** Includes Siltec Silicon

ATTACHMENT E

THE OVER-PERFORMERS

Growth (%) In WW $ Sales

	Actual	Forecast		
	1990	1991	1992	1993
ADVANCED PHOTORESIST	20	37	50	20
REFRACTORY METAL TARGETS	39	33	18	16
GaAs AND GaP	21	17	18	16
SPECIALTY GASES	12	15	17	15
PHOTORESIST ANCILLARIES	10	16	11	12
ALUMINUM TARGETS	20	14	15	14
LEADFRAMES & BONDING WIRE	5	14	18	16

AVERAGE GROWTH

Growth (%) In WW $ Sales

	Actual	Forecast		
	1990	1991	1992	1993
SILICON WAFERS	8	10	10	10
BULK GAS	7	8	8	8
POSITIVE PHOTORESIST	6	11	8	4
WET CHEMICALS	8	10	8	8
MULTILAYER CERAMIC PACKAGES	0	8	8	9
SEALS LIDS	6	9	10	11
MOLDING COMPOUND	6	7	8	7
DIE ATTACH ADHESIVES	7	9	11	12

THE UNDER-PERFORMERS

Growth (%) In WW $ Sales

	Actual	Forecast		
	1990	1991	1992	1993
MASKS	4	5	5	5
NEGATIVE PHOTORESIST	-2	-2	-2	-2
CERDIP PACKAGES	0	0	-2	-2
PRECIOUS METAL TARGETS	9	1	3	3

WAFER FAB MATERIALS DEFINITIONS AND ASSUMPTIONS

- All Forecasts In Current Dollars
- $1 = 140 ¥
- Silicon Wafers - prime polished merchant value, including captive & epi
- Other Substrates - wafers only, no epi
- Photoresists - no ancillary products

WW WAFER FAB MATERIALS FORECAST

(Millions of Dollars)

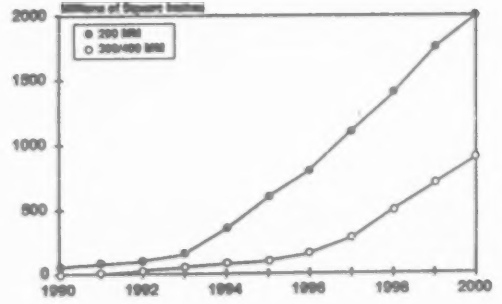
	Actual	Forecast		
	1990	1991	1992	1993
SILICON WAFERS	2010	2215	2440	2680
OTHER SUBSTRATES	245	285	337	390
PHOTOMASKS	1100	1155	1213	1273
PHOTORESISTS				
POSITIVE	168	185	203	211
NEGATIVE	52	51	50	49
ADVANCED	22	30	45	54
WET CHEMICALS	427	468	506	546
GASES	590	661	752	845
DEPOSITION MATERIALS	260	284	312	346
TOTAL	4864	5334	5858	6394

WW WAFER FAB MATERIALS FORECAST

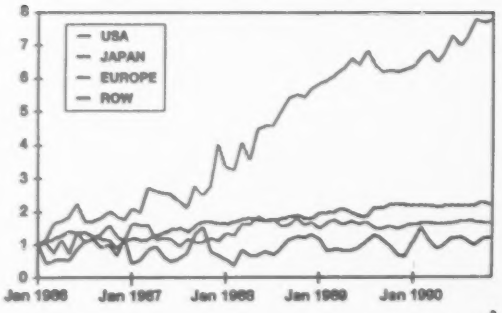
(Units)

	Actual	Forecast		
	1990	1991	1992	1993
SILICON (MSI)	1714	1884	2052	2239
PHOTORESISTS (K GALLONS)				
POSITIVE	446	501	542	565
NEGATIVE	505	495	485	475
WET CHEMICALS (M POUNDS)	376	394	413	443

LARGE DIAMETER SILICON WAFER FORECAST



WW EPI CONSUMPTION



ATTACHMENT G

WW PROCESS CHEMICALS MARKET

	Actual	Forecast		
	1990	1991	1992	1993
ACIDS & BASES				
M$	319	348	377	407
M lbs	306	321	337	364
SOLVENTS				
M$	112	120	129	138
M lbs	70	73	76	79
TOTAL				
M$	427	468	506	545
M lbs	376	394	413	443

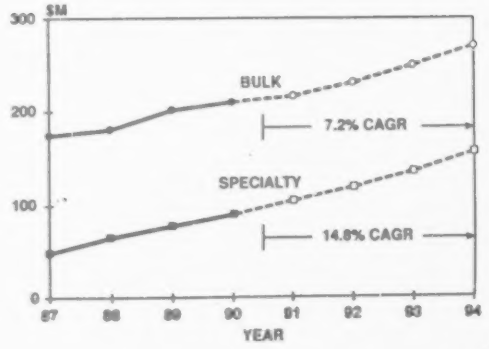
HIGH PURITY PROCESS CHEMICALS

- REQUIRE PURITIES THAT MAY NOT BE ACHIEVABLE
- INTERNAL DELIVERY SYSTEMS NOT COMMON IN USA
- DEVICE MAKERS UNCOMFORTABLE WITH CHEMICALS
- MORE USE OF REPROCESSORS FOR H_2SO_4 AND HF
- VAPOR PHASE PROCESS LINKED TO CLUSTER TOOLS

GAS TRENDS

- MORE REGULATION WITH GREATER RESTRICTION
- HIGHER PURITY
- INCREASED GLOBALIZATION OF MARKETS
- LONG TERM CONTRACTS FOR "FULL SERVICE"
- HIGHER PRICES FOR PROCESS GASES
- LARGER WAFERS/SINGLE WAFER PROCESSING
- FEWER VENDORS

USA GAS CONSUMPTION



COMPOUND SEMICONDUCTOR DRIVERS

- LEDs IN COPIERS, PRINTERS, AND AUTOMOBILE TAIL LIGHTS!
- TRANSISTORS FOR DIRECT SATELLITE RECEPTION (JAPAN)
- COMPUTER MARKET FOR IC's (FINALLY!)
- SUBSTRATE WILL GROW AT +15% PER YEAR

FORECAST OF GaP AND GaAs REQUIREMENT

(Million Square Inches)

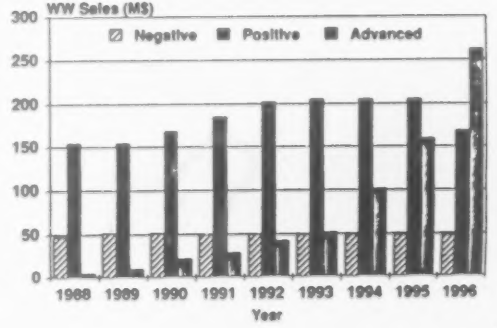
	Actual		Forecast	
	1988	1990	1992	1996
GALLIUM PHOSPHIDE	1.07	1.30	1.60	2.30
GALLIUM ARSENIDE				
OPTOELECTRONICS	1.13	1.59	1.79	3.02
SEMI-INSULATING	0.72	0.95	1.30	1.90
OTHER SUBSTRATES	0.80	0.70	0.60	0.60
TOTAL	3.72	4.54	5.29	7.82

PHOTOMASK INDUSTRY 1990-1995

- CONTINUED IC FEATURE SIZE REDUCTION
- FOURTH GENERATION PATTERN GENERATION EQUIPMENT
- NEW INSPECTION AND REPAIR EQUIPMENT
- NEW METROLOGY EQUIPMENT
- ADVANCED CLEANING EQUIPMENT
- LONGER PRODUCTION, INSPECTION AND REPAIR TIMES
- FEATURE SIZE BARRIER LOOMING

ATTACHMENT I

THE SUPER-GROWTH MARKET: ADVANCED RESIST



Mr. VALENTINE. Mr. Coder?

Mr. CODER. Chairman Valentine, Mr. Lewis, other members of the committee, KTI Chemicals, Incorporated, a wholly owned subsidiary of Union Carbide Chemicals and Plastics, is a supplier of photolithographic chemicals to the semiconductor industry. Our primary products are photoresists and their developers.

KTI's 1990 sales were approximately $25 million, two-thirds of which were resists and developers. KTI has not made a profit in the last three years due to the increased costs of meeting tighter product specifications, providing the engineering support required by our customers, the expenses of expanding our operations to Europe and Korea, and the increased cost of research and development for advanced photoresist products.

Photoresists are key materials used in the semiconductor manufacturing process. The worldwide market for photoresist for semiconductor applications was approximately $250 million in 1990. Bill Reed stated that there are 16 photoresist suppliers competing for this business. That is correct. However, the top seven suppliers have 95 percent of the existing business. The leading worldwide supplier is Japanese-owned. Of the leading seven suppliers, one is Japanese-owned, one is European-owned, three are U.S.-owned, and there are two 50/50 joint ventures: one U.S.-European and one Japanese-European. It is estimated that only two, possibly three, of these companies made a profit in 1990. Compare that to 1984, where the top two and five out of the top seven resist suppliers were U.S.-owned companies. In addition, they were all making a profit.

Since 1985, there have been five U.S. companies and one European company which have made the decision to exit the semiconductor photoresist market. It is my belief that the major reason for these firms' decision to exit this market was the poor return on their investment, the high cost of developing the next generation of resist products, updating manufacturing facilities to meet the advanced product requirements for purity and consistency, and the cost of expanding their operations to the export market.

Each new generation of resists costs significantly more to develop than the previous generation. This is primarily because the functional requirements for the photoresist are much more demanding, and the equipment in which it is exposed and processed is substantially more expensive to purchase and operate. Near-UV steppers used to expose a resist sell for $1.5 million. The deep-UV steppers for the next generation of photoresists will sell for $2 million to $4 million.

In addition, the processing and analytical equipment necessary to evaluate research samples is also extremely expensive. The availability of this advanced equipment is necessary to conduct R&D. In the past, the high R&D costs of developing new resist products could be partially justified by applying the knowledge gained to products used in other industries. Today that benefit does not exist. The purity and manufacturing tolerances for semiconductor chemicals far exceeds any other industry's requirements.

There is tremendous duplication of resources and capital equipment between both the competitors and the semiconductor customers in analytical and functional equipment and development of test

methods. To be competitive on a worldwide basis, we must learn how to cooperate with each other to conserve resources and cut costs. Because of the concerns with antitrust laws, we don't talk to each other, let alone cooperate. The Government could play a major role in changing this environment by changing the antitrust laws and by involving the National Labs in leading cooperation among competitors in attacking common technical issues.

Most European- and U.S.-owned semiconductor companies allow a great amount of autonomy to their offshore facilities. This is not true of Japanese companies. The decision on what chemicals to use in an offshore factory is made by the management in Japan and generally is Japanese-supplied material.

The expansion of Japanese semiconductor manufacturing facilities in Europe and the U.S. as their share of the worldwide semiconductor market grows has placed added pressure for the U.S. photoresist suppliers to have a significantly greater presence in Japan. This need is further enhanced by the shift of semiconductor equipment manufacturing from the U.S. to Japan. The Japanese equipment manufacturers typically select the Japanese photoresists to spec their equipment. This puts resist manufacturers without a strong presence in Japan at a disadvantage.

The recommendations that Bill Reed made regarding a study of the U.S. semiconductor materials industry, restructuring of the R&D tax credit, and changing the export controls, outdated antitrust laws, and liability statutes are all steps that should be implemented to maintain a viable semiconductor materials infrastructure. The changes are necessary for the U.S. semiconductor materials suppliers to be competitive. The U.S. semiconductor infrastructure is not healthy and is threatened with extinction without these changes.

Thank you.

[The prepared statement of Mr. Coder follows:]

STATEMENT BY KTI CHEMICALS,INC.

BEFORE THE

U.S. HOUSE OF REPRESENTATIVES

COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY

SUBCOMMITTEE ON TECHNOLOGY AND COMPETITIVENESS

June 11, 1991

P. Jerry Coder
Vice President
Marketing & Sales

Introduction

KTI Chemicals, Inc., a wholly owned subsidiary of Union Carbide Chemicals & Plastics, Inc., is a supplier of photolithographic chemicals to the semiconductor industry. Our primary products are photoresists and their developers. KTI's 1990 sales were approximately $25 million, two thirds of which were resists and developers. KTI has not made a profit in the last three years, due to the increased cost of meeting tighter product specifications and providing the engineering support required by our customers, the expenses of expanding our operations to Europe and Korea, and the increased cost of research & development for advanced photoresist products.

Issues:

Photoresists are key materials used in the semiconductor manufacturing process. The worldwide market for photoresists for semiconductor applications was approximately $250 million in 1990. Bill Reed stated that there are 16 photoresist suppliers competing for this business. That is correct, however; the top seven suppliers have about 95% of the existing business. The leading worldwide supplier is Japanese owned. Of the leading seven suppliers, one is Japanese owned, one is European owned, three are U.S. owned, and there is two 50/50 joint ventures, one U.S./European and one Japanese/European. It is estimated that only two, possibly three of these companies made a profit in 1990. Compare that to 1984, where the top two, and five out of the top seven, resist suppliers were U.S. owned companies. In addition, they were all making a profit.

Since 1985, there have been five U.S. companies and one European company which have made the decision to exit the semiconductor photoresist market. It is my belief that the major reason for these firms' decision to exit this market was the poor

return on investment, the high cost of developing the next generation of resist products, updating manufacturing facilities to meet the advanced product's requirements for purity and consistency and the cost of expanding their operations to the export market.

Each new generation of resist costs significantly more to develop than the previous generation. This is primarily because the functional requirements for the photoresists are much more demanding, and the equipment in which it is exposed and processed is substantially more expensive to purchase and operate. Bill Reed mentioned that the steppers used to expose the resist sell for $1.5 million. That's true for near UV aligners, however; the Deep UV steppers for the next generation of photoresist will sell for $2 million to $4.0 million. In addition the processing and analytical equipment necessary to evaluate research samples is also extremely expensive. The availability of this advanced equipment is necessary to conduct the R&D.

In the past, the high R&D costs of developing new resist products could be partially justified by applying the knowledge gained to products used in other industries. Today, that benefit does not apply. The purity and manufacturing tolerances for semiconductor chemicals far exceeds any other industry's requirements.

There is a tremendous duplication of technical resources and capital equipment between both the competitors and the semiconductor customers in analytical and functional equipment and development of test methods. To be competitive on a worldwide basis, we must learn how to cooperate with each other to conserve resources and cut costs. Because of concern with antitrust laws, we don't talk to each other, let alone cooperate. The government could play a major role in changing this environment by changing the antitrust laws and by involving the national labs in leading cooperation among competitors in attacking common technical issues.

4

Most European and U.S. owned semiconductor companies allow a great amount of autonomy to their offshore facilities. This is not true of the Japanese companies. The decision on what chemicals to use in an offshore factory is made by the management in Japan and generally is a Japanese supplied material. The expansion of Japanese semiconductor manufacturing facilities into Europe and the U.S., as their share of the worldwide semiconductor market grows, has placed added pressure for the U.S. photoresist suppliers to have a significantly greater presence in Japan. This need is further enhanced by the shift of semiconductor equipment manufacturing from U.S. to Japan. The Japanese equipment manufacturers typically select a Japanese photoresist to spec their equipment. This puts resist manufacturers without a strong presence in Japan at a disadvantage.

Recommendations:

The recommendations that Bill Reed made regarding a study of the U.S. semiconductor materials industry, restructuring of the R & D tax credit and changing the export controls, outdated antitrust laws and liability statutes are all steps that should be implemented to maintain a viable semiconductor materials infrastructure. The changes are necessary for the U.S. semiconductor materials suppliers to be competitive. The U.S. semiconductor infrastructure is not healthy and is threatened with extinction without these changes.

Mr. VALENTINE. Thank you, sir.

We have been joined by Mr. Marc Newkirk, and we are happy to hear from you at this time, sir.

STATEMENT OF MARC S. NEWKIRK, PRESIDENT AND CHIEF EXECUTIVE OFFICER, LANXIDE CORPORATION, NEWARK, DELAWARE

Mr. NEWKIRK. Mr. Chairman, let me start by offering my sincere apologies for being late to this very, very important hearing. I was unavoidably detained by transportation difficulties. I'm sorry.

In addition to being President and Chief Executive Officer of Lanxide Corporation, which is located in Newark, Delaware, I'm also Chairman of the United States Advanced Ceramics Association, an organization of 30-plus users and suppliers of advanced ceramics products and services. The issues for Lanxide, frankly, are shared by the industry as a whole.

Lanxide was founded in 1983 to develop and commercialize products based on a novel approach to the fabrication of reinforced ceramics and ceramic-reinforced metals. The market opportunities for Lanxide's products extend broadly across the basic processing, automotive, aerospace and defense, electronics, machine tool, biomedical, mining, and sports equipment industries. These products are developed and commercialized through selected market-focused joint ventures, using individual resources being applied at the venture level in combination with resources of various world class industrial partners and contract funding from the U.S. Government.

Advanced ceramics, as a class of materials, are the hardest, the most temperature-resistent, most corrosion-resistent, most rigid classes of materials and, as such, are very much enabling technology to the future competitiveness of American industry. They will, as a class of materials, drive competitiveness with respect to product longevity, productivity of manufacturing processes, product quality, in many cases, emergent from basic manufacturing processes. They will be a key technology in the area of environmental pollution reduction and energy consumption reduction.

As requested, my remarks today will focus on the issue of commercialization of advanced materials. As the leader of a company which only recently began to commercialize a variety of advanced materials products, I can tell you two things with complete certainty: first, that there is virtually no end to the challenges involved with making advanced materials an American success story; and second, that our industry will not be able to meet all of the challenges alone. Our survival will at times require the strategic involvement of the U.S. Government. Let me explain why this is so.

The advanced materials industry is characterized by a unique and extremely demanding set of circumstances that threaten our ability to compete in the international marketplace. The front end of the business, the initial technology development and process refinements, also the market development, require massive investments. Lanxide, for example, spent on the order of $150 million before we began our first commercial sales, occurring only recently in our eight-year history.

The magnitude of investment required tends to limit feasibility for new market entrants to large industrials. Lanxide's capacity to accomplish this has only been enabled by a combination of strategic funding involvement by the Government, which, frankly, has been of the order of only 10 percent of the capital invested in this area at Lanxide, and liaisons with major world-scale industrials who have provided this magnitude of funding, supplemented by financing, to a much smaller extent, from the financial markets.

Secondly, and unlike any other sector except perhaps biomedical products, advanced materials have an extremely long maturity cycle. It normally takes 10 to 15 years to transition sound technical concepts into commercially viable products. This is a serious issue, considering the increasingly short-term focus of U.S. industrials and the financial institutions that own them.

Today U.S. industrials largely measure their performance totally in terms of quarterly financial results. Long-term strategic investments in R&D and market development are treated as expenses by accounting practice and, as such, deteriorate financial performance by short-term measure. Hence, the tolerance for such investments by major U.S. industrials, the only players that otherwise would have the financial wherewithal to pursue advanced materials in the United States, is almost non-existent.

This is, frankly, underlined today, in Lanxide's case, by the fact that essentially every serious dialogue that Lanxide has today regarding further joint ventures in its technology are with foreign partners. Essentially every one. We have currently one U.S. partner, one foreign partner, and four joint ventures. All of the additional dialogues which we have in the automotive and other areas which are, frankly, proceeding on a serious basis are all with foreign partners. They're the only ones today that appear to have the capacity to make these kinds of investments.

Finally, the capital-intensive nature of our industry places us at a disadvantage with respect to our foreign counterparts who have access to less expensive and infinitely more patient capital. Put more directly, in the current environment, there is simply no way for an American advanced materials company without strategic involvement of Government to compete with foreign counterparts, who recognize the strategic significance of enabling technologies and are willing to spend whatever it takes for however long it takes to capture and support such key technologies in order to ultimately capture the end-use markets that they enable.

This is perhaps best illustrated by the rate at which U.S. advanced materials companies are either dropping out of the industry or being acquired by foreign entities. Specifically in the area of advanced ceramics and inorganic composites, which is the area in which Lanxide competes, by our accounting, during the time of our eight-year existence, we put the number of foreign-acquired and domestic companies exiting the business at 21. Frankly, we have today almost no domestically owned competition in the United States in the area in which we endeavor. There's a very small plug today of domestically owned companies which compete in this area.

The irony here, at least as far as acquisitions are concerned, is that a lot of people place very high value on the technology developed in the U.S., but these people more and more are foreigners.

What can the Government to do ensure the advanced materials industry are an American rather than Japanese or European success story? From a macroeconomic standpoint, the Government must undertake fiscal policies that will drive down the cost of capital and encourage long-term investment by the institutions that are now the primary shareholders of U.S. businesses.

One means of accomplishing the latter would be to institute a graduated capital gains tax structure that rewards the long-term investor. While I encourage the adoption of such policies, I fear that we may all, as entrants in this business, either be foreign-acquired or out of business by the time they could take effect. Consequently, the Government should take the following more immediate steps to bolster the advanced materials industry, which is the keystone to the competitiveness of our overall industries.

First, establish large federally funded advanced materials insertion programs, through which the Department of Defense would qualify and purchase and demonstrate components based upon advanced materials in operational military systems. One of the sole remaining competitive advantages maintained by the U.S., frankly, is the ability of DOD to provide a niche or bridge market for economically immature technologies. Insertion programs of the type described have the added benefit of generating performance and reliability data required by commercial users of advanced materials and products. They additionally allow the industry a route to getting down experience curves and becoming more efficient to give economic basis to the commercial applications.

Second, to create a specific regulatory, for example, DFAR incentive for the use of advanced materials by the Department of Defense. Program managers and others responsible for purchasing military equipment currently have no compelling reason to adopt non-commercial technologies. In fact, because they're charged with producing lowest cost, lowest risk systems, they have lots of reasons not to adopt new technologies and tend to be risk-averse and technology-averse. This needs to change.

Thirdly, allow faster write-down for plants and equipment involved in the manufacturing of advanced materials products. This would certainly aid in capital formation within the industry, which is a key issue for an industry with a long maturity curve.

Fourthly, establish a Defense Production Act program for the purchase of advanced materials components and systems that fit existing or anticipated military needs. Such a program could, for example, fund the purchase of applique armor tiles which were needed for Desert Storm and maintain the industrial base specifically for that purpose.

Frankly, Lanxide's strategy as a means of bridging the gap from laboratory to commercial status has been to attempt to use the Department of Defense as a bridge for moving that technology into commercialization. Unfortunately, although we as a nation are very good at generating technology, we lack a technology policy when it comes to adoption of technology into military systems. We basically develop good technology, throw it out there, and hope it swims.

The implementation of the combination of these initiatives would go a long way toward ensuring the continued competitiveness of

the U.S. advanced materials industry. I'd like to comment for just a moment to say that contrary to many of the public statements which have been made concerning the advanced ceramics industry, the United States, in fact, is today in the lead technologically in the area of advanced ceramics. We have the only technologies today which allow the fabrication of large structures of fully dense ceramic composites. Ceramic composites in particular is an area in which we lead.

We have the only technologies in the area of advanced ceramics which allow the engineering of properties toward the needs of end-use applications. We have the lowest costs potential in our advanced ceramic composite technologies as against any foreign competitor. The issue for us as a nation is taking our leading edge of technology and translating it into industrial competitiveness, and that is the issue for this industry.

We are, frankly, not in a catch-up mode with respect to technology right this minute. Where we are is threatened with an inability to sustain that lead and threatened with an incapacity to turn it into industrial competitiveness, and those are the things which we really need to focus on as a nation.

I'd like to thank the subcommittee for the opportunity to testify today. Again, I apologize for my tardiness in getting here. Believe me, it's not a commentary on how important I believe this industry is or this hearing is. I commend you for recognizing the significance of this issue. Thank you.

[The prepared statement of Mr. Newkirk follows:]

STATEMENT OF MARC S. NEWKIRK

PRESIDENT AND CHIEF EXECUTIVE OFFICER

LANXIDE CORPORATION

SUBMITTED TO

SUBCOMMITTEE ON TECHNOLOGY AND COMPETITIVENESS

OF THE

COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY

U. S. HOUSE OF REPRESENTATIVES

JUNE 11, 1991

STATEMENT OF MARC S. NEWKIRK
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Mr. Chairman and Members of the Subcommittee,

I am Marc Newkirk, President and CEO of Lanxide Corporation, located in Newark, Delaware. I am also Chairman of the United States Advanced Ceramics Association (USACA), an organization of thirty plus users and suppliers of advanced ceramics products and services. Lanxide was founded in 1983 to develop and commercialize products based on a novel approach to the fabrication of reinforced ceramics and ceramic-reinforced metals. The market opportunities for Lanxide's products extend broadly across the basic processing, automotive, aerospace and defense, electronics, machine tool, biomedical, mining and sports equipment industries. These products are developed and commercialized through selective, market-focused joint ventures using its own resources, those of world-class industrial partners, and contract funding from the U.S. government.

As requested, my remarks today will focus on the issue of commercialization of advanced materials. As the leader of a company which only recently began to actively

commercialize a variety of advanced materials products, I can tell you two things with complete certainty: First, there is virtually no end to the challenges involved with making advanced materials an American success story; second, industry will not be able to meet all of the challenges alone. Our survival will at times require the strategic involvement of the U.S. government.

Let me explain why this is so. The advanced materials industry is characterized by a unique and extremely demanding set of circumstances that threaten our ability to compete in the international marketplace. The front end of the business -- the initial technology development, and process refinements -- requires massive investments. Lanxide, for example, spent on the order of $150M before we began to have our first commercial sales occurring only recently in our eight year history. The magnitude of investment required tends to limit feasibility for new market entrants to large industrials.

Secondly, and unlike any other sector except, perhaps, biomedical products, advanced materials have an extremely long maturity cycle. It normally takes 10 to 15 years to transition sound technical concepts into commercially viable products. This is a serious issue given the increasingly short-term focus of U.S. industrials and the financial institutions that own them. Today, U.S. industrials largely

measure their erformance totally in terms of quarterly financial results. Long term strategic investments in R&D and market development are treated as expense by accounting practice as such deteriorate financial performance by short term measure. Hence tolerance for such investments by major U.S. industrials, the only players that otherwise would have the financial wherewithal to pursue advanced materials, is almost non-existent.

Finally, the capital intensive nature of our industry places us at a disadvantage to our foreign counterparts who have access to less-expensive, infinitely more patient capital.

Put more directly, in the current environment there is simply no way for an American advanced materials company without strategic involvement of Government to compete with foreign counterparts who recognize the strategic significance of enabling technologies and are willing to spend whatever it takes for however long it takes to capture and support such key technologies in order to ultimately capture the end use markets they enable.

This is perhaps best illustrated by the rate at which U.S. advanced materials companies are either dropping out of the industry or being acquired by foreign entities. In the area of advanced ceramics and inorganic composites my accounting puts the number of such foreign acquired or

exited companies at 21.

The irony here (at least as far as acquisitions are concerned) is that a lot of people place high value on the technology developed in the U.S. -- but those people, more and more, are foreigners.

What can the government do to ensure that advanced materials are an American -- rather than Japanese or European -- success story?

From a macro economic standpoint, the government must undertake fiscal policies that will drive down the cost of capital and encourage long term investment by the institutions that are now the primary shareholders of U.S. businesses. One means of accomplishing the latter would be to institute a graduated capital gains tax schedule that rewards the long term investor.

While I encourage the adoption of such policies, I fear that we may all be either foreign-acquired or out of business by the time they take effect. Consequently, the government should take the following, more immediate, steps to bolster the advanced materials industry:

- Establish large-scale, federally-funded advanced material "insertion" programs through which the Department of Defense would purchase

components and demonstrate their performance in operating military systems. One of the sole remaining competitive advantages maintained by the U.S. is the ability of DOD to provide a niche or bridge market for economically immature technologies. Insertion programs of the type described have the added benefit of generating performance and reliability data required by commercial users of advanced materials products.

- Create specific regulatory (i.e., DFAR) incentives for the use of advanced materials. Program managers and others responsible for purchasing military equipment currently have no compelling reason to adopt non-commercial technologies. In fact, because they are charged with producing the lowest cost, lowest risk systems, they have lots of reasons not to adopt new technology. This needs to change.

- Allow faster write-down rates for plant and equipment involved in the manufacturing of advanced material products.

- Establish a Defense Production Act program for the purchase of advanced materials components and systems that fit existing or anticipated military

needs. Such a program could, for example, fund the purchase of applique armor tiles which were needed for Desert Storm, and maintain the industrial base created specifically for that purpose.

The implementation of these initiatives would go a long way toward ensuring the continued competitiveness of the U.S. advanced materials industry.

I would like to thank the Subcommittee for the opportunity to testify today. I commend you for recognizing the significance of this issue.

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Mr. VALENTINE. We thank all of you.

Mr. Newkirk, do you feel that your company is competitive now in the foreign markets?

Mr. NEWKIRK. In the sense of having technology which is in wide-scale commercial production and is capable of being manufactured today in volumes and at economics that can compete with foreign competitions, the answer to that, Mr. Chairman, would be no. With respect to having technology which, if driven down experience curves and put into wide-scale commercial production, can beat the competition, our answer would be a very strong affirmative yes, and what we seek is the means by which to do that.

Mr. VALENTINE. We hear—and have from the beginning of the Republic, I suppose—reasons why the Congress should reduce the tax burden in this area or that area. That's understandable. I mean, we'd all like to be in a position to pay a smaller amount of what we are earning in taxes to the Federal Government and the State and local government. I'm sure you and others can understand the reluctance of Congress to rush to a judgment on this question in the two areas that keep reappearing—that is, tax break and antitrust legislation. Indeed, if that's the solution, then I for one am willing to support that. One of the reasons for all these hearings is to try to find out what the problem is.

As I understand what we're talking about when we say relief from antitrust laws, do we really mean a situation similar to this? That there exists the technology, thanks to cooperative efforts on the part of American business, industry, and the Government, to fabricate or manufacture an automobile engine, including the block, the drive shaft, almost all of it, that is much more doable, much stronger, and much lighter than anything that exists, but a part of the action is spread amongst a group of companies, say 10 companies.

Is the kind of relief that you're talking about immunization from antitrust laws so that these companies can come together and put all the different parts into the puzzle and create this new material that can be sold to automobile manufacturers all over the world? Is that what we're talking about when we say antitrust protection?

Mr. Newkirk?

Mr. NEWKIRK. I'm sorry. I wasn't sure whether you were addressing that to me or not.

I think that the ability for U.S. industry to cooperate back and forth together is key. The CRADAs, I think—

Mr. VALENTINE. In every way? You could come together for that purpose? As a giant corporation, you could fix the price, and you would be immune to competition? Is that what we're talking about?

Mr. NEWKIRK. Well, frankly, while I believe that there are needs—and I'm speaking only for Lanxide Corporation in this response—while I believe that there are needs for cooperation between industrials that have pieces of the puzzle, frankly, I'm not at all convinced that the capacity to do that doesn't exist even under the current laws.

What I don't think we want to do is have an environment where we essentially socialize a piece of technology amongst a bunch of

competitors, because I think the problem with that is that you destroy the incentive that any single competitor has for—

Mr. VALENTINE. I was going to say what about the next step after that? One or more witnesses have mentioned antitrust. What are we talking about? What is business talking about when it comes to Congress and says—

Mr. Reed?

Mr. REED. Yes, I'd like to address that briefly. I don't think we're talking about getting together to set prices or any of that sort of thing, but particularly in the semiconductor business, the cost of doing business is rising tremendously as the product becomes more sophisticated. We're duplicating research and development constantly, and that is a big burden to carry.

If you look at Japan, Japan is able somehow to get together when a product is being developed and to share scientific knowledge. They're not sharing manufacturing techniques, but the minute the product goes into production, they compete very ferociously, as you know if you look at the Japanese industry.

Mr. VALENTINE. Well, if I may be so bold as to ask the question, is that because of the Japanese industry or the Japanese government?

Mr. REED. I don't know. I think it's culture. I think there's a lot of gray area in antitrust in the United States when it comes to small companies. They're afraid to discuss. Now, if you take Semitech, Semitech has done a lot to dispel this and to bring companies together before the production of something. Now, this is what we're talking about.

I think we need to have some legislation that clears up. I don't think it's clear from Administration to Administration what the policy of the Government is on antitrust. It depends on who you have in office. So a little clearer definition would be in order, I think.

Mr. VALENTINE. Dr. Millburn?

Dr. MILLBURN. Yes, Mr. Chairman. I think part of the problem is the perception of industry and the fear that they'll be subject to antitrust actions which may not be appropriate, and that, of course, then commits the senior manager in the company for a long time to fight that and diverts them from other things.

Also, I don't think there's a real risk anymore in the types of things we're talking about of companies getting together and setting prices. We no longer have an insular national market. We now have a global market, and we have to compete from the global market. If General Motors tried to set prices in concert with Ford and Chrysler on automobiles, the Japanese would certainly flood us quickly with automobiles. The prices no longer are determined by U.S. industry alone.

Mr. VALENTINE. Dr. Good, I just have one or two more questions, and I'll yield to my colleagues, and then I will try to come back and try to clean up a bit, in the sense that I will get off my chest all these unasked questions.

Dr. Good, what's the role of international relations and cooperation on these issues, in your opinion? Is it us against them? Is the world divided? Is there a line out there somewhere in the ocean or

the sand? Are there advantages to be gained by international cooperation?

Dr. GOOD. Well, first of all, I think that we've gone so far down the road to a global economy today that the question probably is moot. International cooperation today is a thing that's here, and there's not much that we can do except try to exploit it the best we know how. I think the whole issue of being able to compete in the global market means global and international cooperation, because you won't be able to compete in the European market unless you are willing to collaborate and to cooperate and to actually do some work in Europe. I mean, that's just the way the markets are developing.

I think the advanced materials area is a very interesting one, and I think the dilemma that all of us feel, and I think it's really kind of interesting the comments that were made today, because it's the first time I've ever been at a hearing like this where all the comments are essentially the same, which is a very unusual situation, because these are very different folks sitting here before you today.

The issue is that we have put a lot of money in the United States over the last 50 years, beginning right after the war, in materials. People understood the advantage of that, and in the bulk materials we've done very well. We really have. We've done very well with that. The issue comes on the so-called advanced materials, and the semiconductor group at the end of the table is absolutely one of the best cases in point. These are very small volume materials, and you heard the gentleman from KTI say that the entire industry for semiconductor chemicals is $250 million.

Now, you cannot afford—it doesn't take a degree in economics from Harvard to understand that you cannot afford to put $250 million of research over five years and $150 million in capital for a $250 million worldwide business. Like I said, it doesn't take very much economic background to understand that that's not going to fly. Your shareholders are not going to be very happy about that.

So the issue comes down to how do you—these are enabling technologies, in a sense. They're small-volume, enabling technologies. What they sell is what makes the electronics in your house work. Somehow we have to understand how to handle enabling technologies, and we in the United States have done all of the fundamental research. We are eons ahead of anybody else in the world in the research level and the technology development of these materials.

The issue you have on the table is how do we then make any money out of those? How do we get them into a mechanism where they are actually economically feasible? The example that he gave you for Hewlett-Packard, who doesn't even sell their semiconductor product on the market—they make it only for their own internal consumption—they get their money back by making a computer and then marking the computer up to pay for the semiconductor material that went in the computer. That's one of the ways to do it, that kind of vertical integration.

Now, the issue, then, though, is that many of the products you would like to have—I notice that some of the consortiums that we were talking about, many of them are with just the users, and it leaves out the people who know how to make the materials. The

people who truly know how to make the materials are the chemical industries. Those are the guys who know how to go in the field, build a plant, and make that material. They don't have a mechanism presently for getting their money back, and that's the issue.

Somehow we have to work out ways to either collaborate with our users, which some of us do, by the way, and build in proprietary positions on that material so we can ask a price that will allow you to pay for it, but it's a very unique industry. And what is happening is that some of the Japanese firms understand that enabling technology, so they're buying up some of these firms, and they will indeed put that in their product, and they'll get their money back on the final product. And in many cases, if they own that enabling technology, they can also then stymie us if we try to build a product, because you can't make it because you don't have the enabling technology to put it on the street.

So the issue of foreign, you know, international cooperation, I think, is simply on the table. We have to be able to do that, but we have to be able to do it in such a way that we don't ship the value-added. The issue, as far as I'm concerned is that we want to quit doing the non-profitable stuff here, and letting the technology go somewhere else, where they're building the value-added in and shipping it back to us and getting the profit out of it.

Somehow we have to be able to stop that decline, and I think that's the issue on the semiconductor materials is how do we get back where we're not just selling silicon, but how do we get back where we're making the product that uses that silicon so I can charge for that product and get my value back? So there's an infrastructure problem in advanced materials. It's really a very serious one.

Now, the aerospace business is better than most, and the reason is because of the Defense Department programs, because you have Mantech, you have the manufacturing issues, you have all the materials laboratories at DOD, you have all of those where you can go if you have an advanced material, you can work with those guys, you get some help with the up-front R&D, and particularly you get help with the product development, because they will get it on their airplane and whatever.

So we have a mechanism in the aerospace industry presently through the Department of Defense programs. I mean, if you look at it, there's no other way to come at it. But we have there the opportunity to get those materials into the aerospace industry. We're doing that, and we're doing it really quite well, frankly, but it takes 10 years to get an advanced material qualified in the aerospace industry. So here you've got the up-front R&D to do, you've got a 10-year development cycle to get it certified to use, and the total market when I'm done may be $50 million. That's a really tough situation.

So if you can't get some help on the R&D up front and get some help on the product development, it just ends up not being economic, and that's the issue. Now, so long as the aerospace companies stay here and we get some up-front like the NASP programs and the advanced tactical fighter—the ATF is probably the best vehicle for advanced materials in the country at the moment. So, you know, those are the kind of issues you have on the table.

And the issue with respect to capital is going to come back every time you talk to this group. The issue of how to get capital at a price that you can afford to do this is going to continue. Nobody does anything about it. Everybody talks about it, and nothing changes, but the cost of capital is simply too high to do anything about it.

Mr. MINETA. Mr. Chairman, would you yield?

Mr. VALENTINE. Yes, I yield to the gentleman.

Dr. GOOD. I'm sorry. I preached a little bit, Mr. Valentine.

Mr. VALENTINE. That's all right. That's what we want.

Mr. MINETA. How long is the life of that technology, even if you develop it? And you say the entire universe is $50 million or $250 million, but it's obsolescent in three years or whatever it is. How can we continue?

Dr. GOOD. In the semiconductor industry, that's also correct that it also has a short lifetime. Fortunately, in the aerospace industries, and, again, that's one of the reasons we've been more successful with the introduction of advanced materials, there the lifetime's a great deal longer. Because once it gets certified, then it's going to be there for a while, and you're going to build a lot of airplanes on that certification.

But in the semiconductor industry, you're correct. The turnover there—and there have been some charts drawn there, and the fellows at the end of the table can do it better than I—but there has been some charts drawn there where you can see that every generation of electronic materials, it doubles the price, and the capital goes up in terms of the manufacturing. So it just snowballs in addition to being long-term.

But at least in the aerospace advanced materials business, it's a little different, and there you do get a longer term window, so if you get something certified and utilized, then you can sell it for a fairly—you can calculate indeed how long it will be there, and you can calculate what kind of things, so you can make some decent judgments on what the value of the technology is.

So there's a difference, and that's one of the other issues. You need to understand there's quite big differences between the advanced materials that go into the aerospace issues and the advanced materials that go into the semiconductor issues. Perhaps even some difference in those that are in the ceramic issue at the moment, too.

Mr. VALENTINE. Dr. Good, you—and I don't want you to apologize for preaching. You know, we want a frank discussion, because we mean business, and we are going to give it our best shot. In addition to your comment that everybody talks about it, but nobody does anything about it, isn't it true that American business and industry is afraid to even talk to each other about some of these problems because of antitrust? That we are having these discussions here, you come and talk to appropriate committees of the House and Senate, but you think that, depending on what the chief executive—the President's policies might be, if you talk to each other too much, you might be litigated by the—

Dr. GOOD. There are surely some issues there in terms of antitrust, and the issue of how to get together, you know, and the semiconductor industry has tried it a number of times without as much

success as one would like. The Semitech thing, I think, is a real experiment, and I'm delighted that it seems to be going well at the moment.

But it is true that the possibility of forming some R&D development partnerships in advanced materials between materials suppliers and users could turn out to be very, very helpful, because you can divide the cost, and the fellow who's providing the material could hopefully get a piece of the value back from the product.

And it is true that the industry is still somewhat reluctant to make those kinds of agreements, because they don't truly know how they're going to be looked at. We truly don't understand the rules very well, I think, is what I'm saying. We believe today actually that we could probably do that under the current rules, and it would be okay. But you talk to your legal people, and they say, "Well, yes, but if it isn't, it's going to cost you a bundle."

Mr. VALENTINE. Well, I will recognize the distinguished ranking member, Mr. Lewis from Florida. I'm sure he has questions.

Mr. LEWIS. Thank you, Mr. Chairman.

Mr. Reed and Mr. Coder, today more than ever before it is possible to produce materials and have the exact combination of properties—desired strength, lightweight, temperature corrosion. In your opinion, what do you think will be the status of materials research 10 years from now? Will the changes be gradual, or do you think we'll have superconductivity type of breakthroughs, and then they remain stagnant, and someone else picks up the ball and runs with it?

Mr. REED. I think we will have a lot of changes. I think there's a lot of opportunity for investment, and I think the United States will lead in the development of these materials, but I think as soon as we develop a material, it will go offshore to be manufactured if something is not changed.

Manufacturing has seemed to—we've lost the skills somehow, and this is one of the problems we face when we compete with a country such as Japan, where they have a vertical structure of their industry. A vertical chain means that they're looking for the output at the end, and any one link can lose money, be strong or weak, and they will get something out at the end.

But in the United States, most of the companies are small that are doing this kind of work. They're very innovative. They don't have the funds to develop it into a manufacturing, and if they did have the funds, the market is somewhere else. It's not here. We need an end-product market in this country. In the days when the General Electrics and RCAs were making radios and television sets, there was a chain of supply. It enabled an infrastructure to develop and grow, but we're losing that in the country now.

And to answer your question, the universities will continue and the research labs will continue to turn out these marvelous products, and more and more, the manufacture—they're not going to be elements anymore, they're going to be manufactured materials that require great sophistication to find, to develop, and to manufacture, but I don't think it's going to be done here unless something changes.

Mr. LEWIS. I'd like to just come back again to the vertical integration. What seems to be the problem in the United States? Is it

antitrust that we just can't get into this type of movement? Is it because smaller units are afraid by forming consortiums that they'll lose their technology and there will be technology taken that would disallow a group to move forward toward an end product?

Mr. Reed?

And I'd like to ask Mr. Newkirk the same question.

Mr. REED. I think we've lost the desire to manufacture things in this country, it seems to me. The competition from the world is very tough, very difficult. Governments, despite treaties and so forth, help their industry. We don't seem to get that kind of encouragement, and I hate to be sitting here whining like this. It's not my style.

Mr. LEWIS. This is your place.

[Laughter.]

Mr. REED. I think the Government could help a little bit in developing and manufacturing once again in this country. We don't have any inherent disadvantage. We have all the advantages. We have the work force, we have educational facilities to turn out the new ideas, we just need something to get us going. We need an engine to drive us, and I guess I'm at a lack of words to describe this any further.

Mr. VALENTINE. If you would yield just a minute, do we have an adequate work force?

Mr. REED. Oh, I think so. Absolutely. Absolutely.

Mr. VALENTINE. What about the terrible illiteracy rate in some parts of the country? What does the future hold for that sort of thing?

Mr. REED. Well, of course. I mean, you're absolutely right. As we develop a more sophisticated product line, you have to be able to read and you have to be able to do mathematics. I mean, you're right. This is a danger that is coming unless we rectify our educational system. That's one of the things we as an association constantly strive to do in our local industries. If we can't find a work force, we educate one. But you're right. But I don't think that's currently the problem.

Mr. LEWIS. Mr. Newkirk?

Mr. NEWKIRK. With respect to the antitrust issues, I think the issues may be different, depending upon the segment of the advanced materials industry. For example, if you're in a situation where you've largely started to lose the battle, and you're now increasingly behind, and you're looking for a way to catch up and leapfrog technologically, I think the need for the industry to be able to cooperate laterally within itself and spread risk probably is there, and I think Semitech is an example of that.

If you don't think that you're behind yet, or as a matter of fact, if you think you're ahead, which is basically the position that I believe the U.S. advanced ceramic industry is in today technologically—not in terms of commercialization, but technologically—your desire for lateral cooperation simply isn't there, and your issues are very different. Your issues are how do you exploit your technological lead, not how do you develop one, and to exploit it, you don't need lateral cooperation, you need capital, you need patient capital, you need vertical integration or vertical cooperation, which

is not a problem from an antitrust point of view. So I think depending upon the segment of the industry and where it's at, the issues are different.

I certainly echo Mr. Reed's point with regard to the importance of end-use markets. If you lose the end-use markets, it doesn't matter what you have technologically at that point, because your only market to exploit the technology is the guy that has the end-use markets, and, frankly, that's increasingly an issue for us, for our company, as we look at the auto industry. We look at the auto industry having its market share eroded continually, and we say, you know, where do we cooperate? If you end up picking the wrong horse, you end up losing, because in the end you can only play with the guy that's got the end-use market, and that's an issue.

The loss of the infrastructure is a one-time event. If you lose the end-use markets, having technological superiority doesn't ever gain them back for you, because your only market for the technology at that point is the guy that's got them.

Mr. LEWIS. Mr. Chairman, I have a couple more quick questions, I think.

Dr. Good, you mentioned global economy, and as we look to the EC gains and the Japanese gains—and you, in your testimony, specified that most of your materials are acquired through the subcontracting process, I believe—do you think the United States will be competitive in materials research and production 10 years from now?

Dr. GOOD. I think in materials research we'll be competitive without a doubt. We have really the best university system of materials research in the world. It's the envy of the world. In fact, we have lots of folks from Japan and Europe who are here harvesting that every day.

Mr. LEWIS. I like the word "harvesting."

Dr. GOOD. It's an appropriate term. It's not stealing. There's no law against it. It's stealing only if it's against the law. It's not against the law.

So the point is I think that we will indeed be very competitive there. We just have excellent programs, and one of the issues we want to be sure we don't do is we don't want to throw the baby out with the bath water here. You don't want to stop that, because that's the base on which we hopefully can move forward.

But with respect to the utilization of them, I'm not nearly so sanguine, because some very good folks have played in that game and have decided they cannot make it and have stopped. I think the comments that Mr. Reed made, for example, about the fact that the people who started the semiconductor chemicals businesses were the DuPonts and the Dows of the world, and they're not in that business anymore. These are not unintelligent people. They have stockholders, and they have to make a profit, and they understand how to do that, and they do it very well. And what they're saying is that under the infrastructure we presently have, that business isn't profitable enough for them to continue to pour resources down it and hope it's going to get better. And many of them did it for a very long time.

So the issue there, I think, is a lot less clear, and it has to do, again, with how do you get these materials into the end product,

because you've got to be able—see, the materials supplier has to be able somehow to get a piece of the value of the end product, because these are very specialized materials.

One of the things that is going to change in 10 years is the way you do the research. We're going to be able to design the material specifically for an application. That's going very well right now, and in 10 years from today, I'm convinced that you'll tell me what the application is and what properties you want, and we'll be able to design that material. I think that's a given. Now you've got an even bigger dilemma, because now I have a custom business, and how do I do the capital to do a custom business?

One of the things that we're looking at in our own company is the whole issue of how to totally rethink about how we might produce such things. Is there new processing? Is there a way to look at the—you know, can we look differently at how we make these materials? In other words, could I build a small factory that might make 10 advanced materials, not one, but would be versatile enough to make 10? Could I design a factory and a processing situation which would allow me to do that? That's the kind of innovation that's going to have to happen to get out of this dilemma. The question is how to get the cost out so that these things become cost effective in a custom mode.

And we're in a transition at the moment. The people who know how to do that kind of processing are mostly the chemical industry. They're used to making money on large-volume materials. For example, in our fiber plants, if I can redo the process and I can get a penny out of the cost, it means an enormous bang to my bottom line. That's not true in these materials we're talking about here. I can get $10 million out, and I'm still nowhere, because the whole volume isn't big enough to support that process design.

So I think this sort of transition between the folks who know how to make these things and this customized kind of an approach to the world, which we really haven't managed, and the people who have managed it vertically integrating, like the situation that Hewlett-Packard has where they learned to make that crucial material for themselves—they may not even be the best people in the world to make it, but they get their money back by selling you their computer, and they don't care whether that particular aspect of their business loses money or not. It's not important. It's just a part of the expense, and the issue is does the whole thing make money?

So it's a question of infrastructure really and how we go about trying to do that. So some innovative research—and I would like to see some innovative research programs in processing take place, where the chemical engineers and the mechanical engineers and the engineering community was asked to truly look at, you know, how do we rethink about how we manufacture materials?

So the answer to your question is that I think in research, yes, we'll be competitive unless we stop what we're doing, but with respect to the materials, it's not a given.

Mr. LEWIS. Thank you, Dr. Good.

Mr. Chairman, just two more questions. I want to ask Dr. Schwartz a question.

The OSTP report on April 25 of this year stated, "The United States needs to improve materials synthesis and processing." In

your opinion, how could the United States best accelerate materials synthesis and processing?

Dr. SCHWARTZ. Well, I think Dr. Good made an extremely important point. The fact is that in very few instances has the R&D funding from the Federal Government that has gone into the materials research arena been focused on materials processing and synthesis. One finds that in most chemistry departments, inorganic synthesis is an activity which had nearly disappeared by the 1980s. The changes in that direction have already begun in some of the departments.

In many of the materials departments, synthesis and processing has become a topic for discussion in the mid- to late 1980s. Adequate resources for carrying out programs in this arena, however, don't exist, and again to refer to a statement that Dr. Good made earlier, a new program that's been initiated at the—or rather proposed at the NSF for the 1992 fiscal year addresses or begins to address that issue.

So the first step is simply awareness at the universities that this is an important area of activity and that it needs to be included in academic circles. Secondly, I think our experience in synthesis and processing materials for defense applications, as has been noted by several of the speakers, demonstrates that it can be done very effectively when cooperation exists between the activities in the industries, which are the ultimate manufacturers, and the Government laboratories, which have the goal of producing materials for defense end-use. The possibility for a combination of such laboratories with other end-users is there. We just have to learn how to do that effectively.

In my written testimony and the example that I gave you earlier, I've indicated the possibility for doing that kind of thing has already been demonstrated in a number of instances, and I might just add to that observation that in one of the examples that I submitted in writing, we have in fact created an ad hoc consortium to carry out a particular bit of process research which is of interest to the aerospace industries, and in that consortium, in the second round, which is presently under finalization, we are going to have the cooperation of two materials producers, two materials users—two major aircraft engine manufacturers—and other departments of the Federal Government as well.

So there are opportunities of this kind. That doesn't answer all of the technological issues, but it does mean that when we find critical needs, we can find ways to cooperate.

Mr. LEWIS. I'm very interested in your statements. Most of you mentioned that you need help from the Government. You know, a couple of the greatest lies are "The check is in the mail" and "I'm from the Government, and I'm here to help you."

But what I'm concerned about, I guess, is what role the Government should have once technologies leave the development laboratory, and are legislative initiatives necessary to enhance United States competitiveness? And as a free enterprise advocate, when we try and when legislation is produced in Congress in order to, in some people's viewpoints, expand competitiveness and help business, there's a tremendous groundswell from the free enterprise

system in opposition to this, and, you know, they want the Government to mind their own business and stay out of your business.

But I'm hearing you and numbers of other panelists making the same comments over the past weeks. I'm just wondering if you could comment on what you feel the Government's role is once technologies leave the development laboratory, and are legislative initiatives necessary to increase United States competitiveness?

Mr. NEWKIRK. I think the Government does have an important role following that. I know that there's a lot of divided opinion around this question these days. Speaking as a businessman, I think classically businessmen's views toward Government has been in the past, "The best thing the Government can do is leave me alone." Well, today the global environment has changed. I think that is not an appropriate view for the industry or for the Government today.

I know there's a lot of comment from time to time about picking winners and losers and the Government isn't good at that. The fact of the matter is, I think, that the Government has had historically an enormous impact on its industrial base. Whether intentional or unintentional, I think it is quite factual.

I think in three massive war mobilization efforts, I think the Government drew very heavily off of its industry and by the close of World War II, for example, had yanked its aluminum business, its chemical business, its steel business, its plastics business onto its feet, whether intentionally or unintentionally, to meet national priority needs at a time in which, for various reasons, effectively all of our would-be competitors around the world had been bombed flat. In that particular scenario, I would submit that intentionally or unintentionally the Government had an enormous effect on its industrial base.

Well, today I don't think what we're looking for necessarily is for the Government to subsidize its industrial base so much as to use the precious resources that we are spending more effectively, and today we still spend, even in a planned decline in spending, an enormous amount on the defense industrial base. Our defense strategy is one of technological superiority. That is compatible with the idea of drawing off of economically immature technology. I think we need to get better at doing that. Certainly, Desert Storm was an excellent example of the importance of technological superiority in warfare.

I think our military strategy has been the right one. I think we're not as effective today at drawing our key technologies into the military sector as we have been in the past, and I think we need to get more efficient at that, given the fact that we're spending less in the military sector. I'm not even proposing that we spend more—I recognize those realities—but I think we need to get more effective at the dual use benefits that are available out of that technology.

I would submit that in the advanced materials arena, there would not be a carbon fiber business today here or elsewhere in the world had the Department of Defense not been a key customer in pulling along that technology and utilizing it. I think that the same thing needs to be done for other advanced materials sectors. I think there are needs on the military side. Certainly, armor is one

of the large examples in the advanced ceramics area. There are many others. I think we need to get better at doing that.

Mr. MINETA. Would my colleague yield?

I'm just wondering, even that technology, though, that we experienced in the Persian Gulf, I bet that's 10 years old.

Mr. NEWKIRK. In many cases, I think it is. Sure. Certainly, I can tell you that the ceramic technology that was there, very little of the current technology was being used there. A few of us did send over a very small amount of applique armor for Desert Storm. That was actually very important to us as an industry. I can tell you in our company's case, we went from a 30 percent manufacturing yield to a high-90s percent manufacturing yield in just shipping 20,000 armor tiles to Desert Storm. You know, that kind of leverage, I think, is important, but I think by and large very little of the technology utilized there is stuff in the last five years.

Mr. VALENTINE. Dr. Millburn?

Dr. MILLBURN. I would like to add to that. I think that the Defense Department has developed a great deal of technology, and I think probably the Government certainly spends the most money on developing technologies. There are several things I think the Government could do, but the two most important things are to maintain the Science and Technology Program overall, contracted work by the Government as well as the independent research and development that industry does, at its current level—$10 billion to $12 billion a year. I think that's the most important thing to do, and as the defense budget goes down, that's going to be difficult to do, but I think it's a matter of priorities and how the Congress looks at it.

Secondly, and perhaps more importantly, is to remove the procurement barriers which exist in the Department of Defense which prohibit the use of commercial practices—not commercial products, but commercial practices—in developing products for the industry. The result of the procurement practices which do exist has been to build walls in companies between the commercial business and the defense business. The total requirements on the procurement accounts that have to be kept because of the adversarial relationship between the Government and the industries there has created these huge barriers and prohibits really the transfer of technology from the defense industry side of the house to the commercial side.

I don't think that people realize what a great impediment that is to the transfer of technologies and prohibits the dual use of many technologies on both sides. It really constrains the defense use of the commercial technologies, and it certainly constrains the application of defense-developed technologies by the commercial market.

Mr. VALENTINE. Thank you, sir.

The Chair will recognize at this time the distinguished gentleman from Indiana, Mr. Roemer.

Mr. ROEMER. Mr. Chairman, I would defer to my senior colleague from California.

Mr. MINETA. I appreciate it, but go ahead.

Mr. ROEMER. I guess I would just like to ask the Chairman's indulgence for a moment, too, as maybe I lecture for a moment after what Dr. Good has said.

I think this whole problem gets down to not looking at what's going to happen 10 years from now; it's happening right now. Dr. Good used the terminology "10 years from now." I come from the Midwest, and one of the reasons I got on this committee was because of exactly what the Chairman has decided to do in renaming this committee and putting forth a competitive technological manufacturing nature of making this country competitive again with anybody and everybody in the world.

This is translating people-wise and job-wise into my district and into the Midwest. People are losing jobs in the manufacturing area where they're getting paid $12 and $15 an hour. They are going to work—skilled journeymen in mill rights are moving from 25-year jobs to jobs where they're janitors in schools making half and a quarter of the amount of money. We have all kinds of problems with people going to work from a factory that is not retooled and can't keep up manufacturing to Taco Bell, where they don't have health benefits, where they're having to work two and three jobs.

And I think it's important that we talk about—everybody on this panel has talked about the technology, manufacturing base, competitiveness, we've talked about our educated work force, our skilled work force, and I think it's important to talk about this in terms of people, too. We seem to have a consensus that the Government has an important role, that we need to look at ways by which, either through education or through cooperation, through new technologies, that we keep our people working at respectable jobs and give them dignity, and if we can win a war in the Middle East in 100 days, we should be able to take care of our middle class in this country. If we can use the best technology in the Middle East, we can manufacture the best technology in the Midwest, and that's what this committee, I hope, looks at.

And I guess with that long introduction, I'd like to just ask a couple people on the committee—we've talked about some of the domestic policies that we can look at, from monetary policy and increased access to capital. What about some of the problems that some of my companies have on the trade barriers and the export regulations that we run into? If a couple of people—

Dr. Millburn, I see you shaking your head there. Maybe you could talk about that, as well as I think Mr. Reed mentioned that in his remarks as well.

Dr. MILLBURN. Thank you, Mr. Roemer.

I think that the inhibiting factor of our critical materials list, which prohibits the transfer of certain materials, is certainly there. That may have been very important at one point. It's becoming less important, and I think it's more important now that we look at the overall economic security of the country, which is an important part of our military security also.

I think inadequate attention has been paid to that, and I think it's quite right that these trade barriers, which are in many cases just inhibiting the flow of technology back and forth because of our fear of someone using them in a military sense, are prohibiting our commercial exploitation of them. That, I think, has gone just a little bit too far, and I think the need for that now has been greatly reduced, but it hasn't been recognized yet in the law.

Mr. ROEMER. Mr. Reed?

Mr. REED. I'd just like to—I don't know if it's true or not, but they're telling me that the new core list of products has come out, and one of the products that was banned was a pizza oven, primarily because of its ability to reach high temperatures.

[Laughter.]

Mr. REED. Now, someone was applying the rules as they were written down, and that's been some of the problem that we've had over the years. There's been an inability of the people making these regulations to understand what the full impact was, and I think we've worked hard at that, and it's diminishing, I must say.

So I think that more important is the class of competition that we're facing in the world today. It's tremendous. You've got to be a first class world operator to understand just how difficult it is.

I mentioned the major market for our products is Japan. Most of our companies are exporting 60 percent of what they make to Asia, and the biggest market in Asia, of course, is Japan. We're able to do business there but at a tremendous disadvantage, because it's a long way from home, the language is very difficult for us, and there is growing competition as an industry matures over there. So it's very difficult for small companies to compete in that world market because of the lack of funds.

The real answer is we have to maintain a market here at home. You cannot continue to ship more than 50 percent of what you make overseas. It will not last.

Mr. ROEMER. I guess that brings me to another question, too. The staff tells me that in order to clarify what the antitrust laws were and have been during the 1980s, the Safe Harbor Act of 1984 was passed which allowed some cooperation between industry in industrial research. And I guess the next question becomes: where do we need to specifically clarify that in cogent terms if people at this committee aren't sure that it's clear enough, and secondly, do we need to take it further to extend the permissiveness and the cooperation to development and production? Especially since almost everybody here at the committee has said, "We seem to, in our R&D, have a big capital R for research and a very small and weak D for development for commercial utilization."

Could you comment on that, Dr. Good?

Dr. GOOD. Yes. I suspect that's correct. The antitrust issue, I think, is there. It's sort of in the background. On the other hand, I don't think necessarily it's the biggest issue. There's no question that it would be helpful if we had some clear staff work done which says that "These are, as we see them, what is legal and proper to do." I think that would indeed be useful. That's hard to get out of a government agency, just a clear statement that says, "These are the things you can do, and these are the things that are illegal." You get a book about that big, and then your legal people take another couple of years to read that.

So the possibility of doing that, I think, could be very useful indeed, and it would be very helpful if it could indeed look at the possibility for collaborative efforts in the development stage as well, because one of the big—as I made the comment in my written remarks, the research part of the business is—in some ways, our part is the cheapest part. The expensive part is the development

and the product development. That's what is extraordinarily expensive.

So the possibility of doing some joint development kinds of things would make a lot of sense. In some of these areas we're talking about, people do it now. That's also true. There are some collaborative things that go on, but, sure, that would be helpful to do. But I think that the bigger issue is the infrastructure problem and the fact that for many of our advanced materials we like to make, the market for the end product is not here, it's elsewhere in the world. Those, I think, are bigger issues, if you would.

Mr. ROEMER. Dr. Schwartz, I'd like to ask you, you said in your testimony that you cannot assume that our National Labs produce something industry wants and then, secondly, that industry can use. We've had different people come before the committee and testify that there are certain things in the labs that would be helpful in the research stage and also in the commercial utilization stage. Are there some specific things that you would recommend that would enhance the ability for industry and Government to cooperate at our National Labs, and are there specific things at our labs now that this industry or other industries would like to get access to?

Dr. SCHWARTZ. Well, I didn't mean to suggest that there weren't in fact examples of specific developments at National Laboratories and at the universities, for that matter, that aren't immediately of interest to industries.

Mr. ROEMER. Like what?

Dr. SCHWARTZ. There are examples of new materials that have been invented at laboratories, new process technologies. Do you want some specific examples?

Mr. ROEMER. Sure.

Dr. SCHWARTZ. The development of many new catalysts has occurred in university laboratories and then been cooperatively transferred to industrial laboratories. The development of some new process technology is currently under way in our laboratory for the manufacturer of silicate nitride, which is of considerable interest. As a matter of fact, there's a possibility for collaboration between our laboratory and Rutgers University which will lead to a completely new way to make that material, and these are activities which have come about as a result of the efforts of individual scientists pursuing the track of new knowledge, if you will.

But my point was, more importantly, that while those things happen, counting on them to happen as a process for taking advantage of the National Laboratory is not a particularly effective or fruitful way to use the vast resources that exist at those laboratories. The programs that exist at those laboratories, when they have been designed and channeled with specific end goals in mind, have been extraordinarily effective.

Many of those laboratories that we're speaking about were involved in the development of many of the weapons we spoke of earlier in the Desert Storm arena, and for that matter, the entire nuclear industry, which came out of the early years of the National Laboratories, is a documentation of the fact that National Laboratories can have an important and effective role if the end goals are defined as part of the process of developing the programs.

My point was simply that with regard to commercial technologies, that's usually not the plan for the research programs. The programs are initiated on the basis of good scientific judgment, but because of the lack of a direct involvement with industry during the planning stages, those programs hit or miss the mark in a more or less random way, and in particular, they tend to stop long before they get into that very expensive development arena that Dr. Good was speaking of because of a focus on research rather than development, and as a consequence, they stop with a product which still requires extensive additional investment by someone to bring it to the point where industry can then take it further into actual commercialization, and that someone normally doesn't exist.

Mr. ROEMER. Finally, Mr. Chairman, one last question.

Mr. Newkirk, I was at a breakfast a few months ago where I believe I saw a product or part of a product that your company is involved in with helping to make the ceramic engines. If you could comment on that, if you can—I believe it was your corporation—and where we can go in that area, where we are in competition with the Japanese, and specifically what that would mean in terms of our manufacturing base if we could get to the point where we can manufacture ceramic engines.

Mr. NEWKIRK. Our company has two areas of our technology, ceramic-reinforced ceramics and ceramic-reinforced metals, concentrating in the latter case particularly on the ceramic-reinforced aluminum, which offer a major impact on engines in automotive systems.

For example, our view is that essentially all of the iron present in a vehicle today—not necessarily steel, but iron in the form of cast iron, gray iron, et cetera—which on the average vehicle is about 225 pounds, can be replaced by ceramic-reinforced aluminum, with a weight savings of about 60 percent when one looks at the difference in properties.

That is, we can create ceramic-reinforced versions of aluminum that have the same stiffness as cast iron but at 40 percent of the weight. Things like engine blocks, cylinder heads, bell housings, axle tubes, brake components, et cetera, we see as being prime prospects for transitioning that technology. The technology is net or near-net shape. It's very low-cost technology and produces very high-performance materials out of commodity grade starting materials.

In our ceramic-reinforced ceramics case, we are demonstrating right now in engine tests the ability to make products which have substantially lower weight and substantially longer wear lives, which have the possibility of extending warranty life on vehicles to longer terms. We believe that this technology, if transitioned into products and commercialized in broad-scale commercial production, would be very cost-effective and would drive, very importantly, the competitiveness of the engine business and the automotive business as a whole.

What we are seeking right now is the routes by which we can do that. We have technology that can do that. The key is how do you turn it into industrial competitiveness?

Mr. ROEMER. Thank you.

Thank you, Mr. Chairman.

Mr. VALENTINE. The lady from Maryland, Ms. Morella?

Ms. MORELLA. Thank you, Mr. Chairman.

I'd like to ask unanimous consent, Mr. Chairman, that a statement that I have prepared be allowed in the record without my repeating it.

Mr. VALENTINE. Without objection.

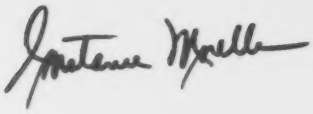
[The prepared statement of Ms. Morella follows:]

CONSTANCE A. MORELLA

SST/T&C SUBCOMMITTEE HEARING

CRITICAL TECHNOLOGIES - MATERIALS

JUNE 11, 1991



MR. CHAIRMAN, MATERIALS ARE ONE OF OUR VITAL PRIORITIES FOR MAINTAINING OUR INTERNATIONAL COMPETTIVENESS. INDEED, THE REPORT OF THE NATIONAL CRITICAL TECHNOLOGIES PANEL LISTS MATERIALS AS ONE OF THE SIX CRUCIAL AREAS FOR OUR NATIONAL ECONOMIC PROSPERITY.

THE ELECTRONICS, AUTOMOTIVE, MEDICAL, AND AEROSPACE INDUSTRIES ARE ALL DEPENDANT UPON RESEARCH AND DEVELOPMENT OF NEW AND SUPERIOR METALS, NONMETALS, AND COMPOSITES. THESE NEW MATERIALS HAVE APPLICATIONS IN CREATING IMPORTANT INNOVATIONS SUCH AS CUTTING-EDGE MEDICAL TECHNOLOGY, LIGHTER AIRCRAFT STRUCTURES, ADVANCED AUTOMOBILE SYSTEMS, AND STRONGER, LIGHTER, AND MORE ENERGY EFFICIENT CONSTRUCTION MATERIALS.

MR. CHAIRMAN, THESE HEARINGS WILL EXAMINE THE ROLE WE, IN GOVERNMENT, SHOULD PLAY IN ADVANCING OUR INTERNATIONAL TECHNOLOGICAL AND ECONOMIC COMPETITIVENESS IN MATERIALS. I EXPECT THE NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY WILL BE IN THE FOREFRONT AND WILL WORK VERY CLOSELY WITH OUR NATION'S INDUSTRIES IN CREATING NEW MATERIALS TECHNOLOGY. I WELCOME DR. SCHWARTZ, NIST'S DIRECTOR OF MATERIALS AND SCIENCE ENGINEERING, AND I LOOK FORWARD TO HEARING FROM HIM THE ROLE NIST WILL PLAY IN DEVELOPING THIS CRITICAL TECHNOLOGY.

Ms. MORELLA. I think this has been an incredible panel, very intelligent with a great deal of experience, and we appreciate your candor in sharing some of the obstacles and opportunities with us. I want to certainly welcome Dr. Schwartz from the National Institute of Standards and Technology—all of you, but he's in the district I represent, and I see him often.

One of the things that I heard kind of repeated that has troubled me recently has been the fact that you've got research taking place at DOD laboratories, and you've got a number of impediments that truly prevents it from going out into the commercial private sector.

Dr. Millburn, you particularly hit on the fact that maybe one of those difficulties is the procurement. I really hadn't thought about that as the impediment. I just thought somehow it's sort of a turf thing, and we don't think about the commercialization and bringing it forth in terms of technology transfer. But maybe it is procurement. Do you think that is the major obstacle?

And then do you think what we can do—I would address this to all of you if you would like to expand on it in any way—what we can do about it.

Before you answer, let me notice also that there was an OSTP report which I think brings up this kind of thing. It concluded that "The United States enjoys world leadership in ceramics research and development. The U.S. industry has been relatively slow to incorporate advanced ceramics into non-aerospace applications." We've seen this in so many other ways, too, if you'd like to comment on it.

Dr. MILLBURN. Thank you, Ms. Morella.

I'd comment on your last question first. I think the other persons here have mentioned the vertical integration, which also sometimes people call the systems approach to developing an end product, because you start at the beginning and get down to the end of the chain, and that is very much what is done in the aerospace industries and in the defense industries. They will have an idea in mind, an end product they want, and they do everything together, and I think that's the reason that the advanced materials are integrated quickly into the products that are produced in defense, and that's the inhibiting factor in the commercial place.

That's not usually the way things are done in the commercial marketplace. It's very seldom that an end product is envisioned, and then there's a chain that leads down to the product, and the others on this panel have mentioned that better than I can.

To get back to the question of the inhibiting of transfer of defense technology, I was with the Department of Defense for 12 years and left about a year ago, and during most of that time, I recognized the fact that in the Government laboratories the individual scientists and the managers are not motivated to understand or to look for commercial applications of their technology. That's best done by the industry, since the industry spends about 50 percent or more of the funds that are spent in R&D in the Defense Department.

For many years, we said the proper way to promote that transfer is to promote the transfer within the industries themselves. It wasn't until I got out into the commercial world that I began to understand better the barriers that were erected quite by accident.

The procurement policies were not designed to do that. They were designed to provide for adequate oversight and accountability of the Government funds that are spent in the defense industry, but they are much more onerous than are the types of reports that are required in the commercial enterprise between two different companies.

The net result of this has been that in meeting the requirements that are set on a defense contractor by the Government to account for where every penny is going, so to speak, the accounting systems that are required are so different that every major contractor has two sets of books that are kept—one on the Government side and one on the commercial side—and these have developed into separate divisions.

If you go out to a major company, Boeing, you have a Boeing Commercial and you have a Boeing Defense, and they don't talk to each other, and the reason they don't talk to each other is because the accounting is so different that it's very difficult for them to use one another and to make the transfer of the technology from the defense side into the commercial side, let alone going the other way.

I didn't really appreciate that until recently, and I think it's one of the major impediments that exists, and I think that anything that Congress can do to make that less onerous would certainly be a move in the right direction. Unfortunately, it's a very long-term thing. It's not going to have an impact in six months or a year. It's going to take some time to break those walls down to get that conversation between the two to occur, but I think it's very important that it be done.

Ms. MORELLA. Would any of the others of you like to comment on whether you think that this is something that we should pursue?

Yes, Mr. Newkirk?

Mr. NEWKIRK. Yes, I believe that transitioning the technology from the laboratory into military systems is a key issue. I think that it's something that can provide a route down experience curves for the advanced materials industries and, at the same time, provide benefits to the Department of Defense.

Basically, there is very little link today between the acquisitions side of the military and the technology development side of the military. We basically develop technology, and then we throw it out there hoping it will swim, and on the procurement side, the procurement is designed around mission statement needs and goes out to the prime contractors, who are not necessarily the ones developing the advanced materials—sometimes yes, but frequently not—and asks them for their bids for a given system.

The system has no technology policy whatsoever. That is, if you have a new technology—tomorrow's technology or today's technology, let's say—and you've got yesterday's technology and yesterday's technology is fully commercial, being manufactured in volume, if yesterday's technology will do the job, tomorrow's technology will not be adopted. And it's, you know, if you'll permit me the analogy, the equivalent of having a large shade tree, which is yesterday's technology, growing in your yard providing you shade, and another sprout coming along, and do you put all the water on the big shade tree? Well, eventually, obviously, the big shade tree dies, and you

don't have tomorrow's technology, because you couldn't provide it a route to grow.

What's happening today is our neighbors are digging up all the shade trees and transplanting them, basically. They're not dying, fortunately, but they're getting transplanted, and, frankly, we see that in our industry very greatly. As I indicated, some 21 of our competitors have either been foreign-acquired or gone out of the business in the inorganic composites and advanced materials area. Some 16 of those were foreign-acquired out of the 21.

We do need more effective routes of doing that, and that's why I had suggested in my testimony the concept of insertion programs. The ceramic tiles which we sent to Desert Storm for up-armoring the Marine Corps LAV-25 were an example of a very accelerated path, taking technology and getting it qualified and fielded on a weapons system. It's now qualified there. Unfortunately, there isn't any budget to now buy them for the LAV-25s, but that's a separate issue.

Ms. MORELLA. You know, maybe, Mr. Chairman—those are very vivid metaphors, incidentally—but maybe, Mr. Chairman, we should plan a hearing where we have some of those people who work with those regulations, who could tell us how it could be changed or how it's operating.

In other words, pick up on what you've said, but those who are actually doing it, so that we can help to bring about some changes.

Does anyone else want to make any comments on that? Certainly, we need to know how to get the materials into the end product. The dual use benefits, I think, are so very important. The antitrust to avoid the duplication. Does anyone else have any comments you want to add? Because I'm not going to go on with anymore questions.

[No response.]

Ms. MORELLA. Thank you.

Thank you, Mr. Chairman.

Mr. VALENTINE. I have to—before recognizing our distinguished colleague from California, Mr. Mineta, let me say, Mr. Newkirk, that whether you water those trees or not, the shade from the big tree will kill the little tree.

[Laughter.]

Mr. VALENTINE. Mr. Mineta?

Mr. MINETA. Thank you very much, Mr. Chairman.

I want to ask unanimous consent to submit an opening statement.

Mr. VALENTINE. Without objection.

[The prepared statement of Mr. Mineta follows:]

JUNE 11, 1991
NORMAN Y. MINETA, M.C.

NORMAN Y. MINETA, M.C.

MR. CHAIRMAN, I CONGRATULATE YOU FOR HOLDING THIS HEARING ON MATERIALS AND MATERIALS PROCESSING, AND I LOOK FORWARD TO HEARING THE TESTIMONY TODAY ON THESE IMPORTANT TECHNOLOGIES, WHICH ARE CRITICAL TO THE UNITED STATES' INTERNATIONAL COMPETITIVENESS.

MR. CHAIRMAN, MATERIAL SYNTHESIS AND MATERIALS PROCESSING HAVE BEEN IDENTIFIED BY SEVERAL REPORTS, INCLUDING THE RECENT REPORT OF THE NATIONAL CRITICAL TECHNOLOGIES PANEL, AS A TOP PRIORITY FOR THE UNITED STATES' COMPETITIVENESS.

THESE REPORTS CONCLUDED THAT, IN A FEW AREAS, SUCH AS MATERIALS PROCESSING TECHNIQUES FOR AEROSPACE, THE U.S. MAINTAINS A LEADING POSITION. THESE DEVELOPMENTS WERE DRIVEN BY THE REQUIREMENTS OF MILITARY AND AEROSPACE SYSTEMS.

UNFORTUNATELY, IN OTHER AREAS OF MATERIALS AND MATERIALS PROCESSING, THE U.S. CURRENTLY LAGS FAR BEHIND EUROPE AND JAPAN.

MR. CHAIRMAN, MATERIALS AND MATERIALS PROCESSING HAVE WIDESPREAD COMMERCIAL APPLICATIONS AND ARE BECOMING INCREASINGLY MORE IMPORTANT TO MANUFACTURING AND OUR ABILITY TO COMPETE INTERNATIONALLY.

THE U.S. MUST ACCELERATE THE DEVELOPMENT OF MATERIALS TECHNOLOGY IN SUCH AREAS AS CERAMICS, COMPOSITES, HIGH PERFORMANCE METALS AND ALLOYS, AND ELECTRONIC AND PHOTONIC MATERIALS, IF WE ARE TO MAINTAIN OUR COMPETITIVE POSITION IN THE WORLD ECONOMY.

THANK YOU.

Mr. MINETA. Mr. Chairman, I want to congratulate you for holding these hearings that you've had. The series have been fascinating and really, I think, bring to the surface and to the focus something that has to be discussed openly.

Last night I had the opportunity, with, I believe, about six or seven, to be at a dinner at the Ambassador of Japan's residence involving the Chairman and CEO of Solomon Brothers, the Chairman and CEO of Allied, Mr. Hennessey, and others. It was a fascinating conversation. But it seems to me that what I heard here three people use—Dr. Good, you said "end-use market"; Mr. Schwartz, you said "end goal in mind"; Mr. Reed, you said "access to the market." They're all saying the same thing, and we don't have it.

It seems to me, as you said, Bill, your members are exporting 60 percent of their products. Japan will welcome your technology until they get it, and then they'll tighten down, and pretty soon our companies will wither and die in Japan, and I don't know how we get this across.

Last night, I'll tell you, I kept saying, you know, "We just signed a semiconductor industry agreement, and your country is saying, 'Yes, yes, we want to cooperate,' but your bureaucrats are saying, 'No, no, no, we'll stonewall them, this will go away in time.'" This is the third three-year agreement for the semiconductor industry, and I don't think we'll ever hit that 20 percent. We're up to 13.7 percent of their semiconductor market after close to six years. Their market keeps on increasing, and we don't get an increasing share of that market.

So from my perspective as a member of Congress, it's frustrating, so it's got to be doubly so for all of you in the private sector trying to make this thing work, as well as someone like Mr. Schwartz at NIST. I'm wondering whether or not the companies will continue to invest in research, development, and I suppose the other aspect of it is applications, meaning the commercialization of product, if we don't get that access to the market or end-use market or, as Mr. Schwartz said, "end goal in mind." Will the companies continue doing this?

Mr. Newkirk, I think you said companies keep looking at the next quarterly results. But given that view of looking at the next quarterly results, will the companies continue investing, and is this why DOD and NASA in the past have been the repository or the place where a lot of this research and development got done, because of some of the other antitrust action and things, fears that the companies had?

And we just had a fight on the floor this past week involving trying to make sure that we got the funding for Space Station Freedom, since the Appropriations Subcommittee had eliminated $1.9 billion of funding for Space Station Freedom, and under the leadership of Chairman Brown of this committee, as well as Mr. Walker and Mr. Sensenbrenner and Mr. Lewis, we were able to get back the funding, at least on the floor, for Space Station Freedom.

But I'm just wondering is even that well starting to dry up at the Federal level? If that's the case, where do we go in the future? Where are we going? Anybody?

Mr. Coder?

Mr. CODER. I think partly what we're talking about are business issues, and as it relates to business issues in terms of advanced technology and the ability to make money on advanced technology, I think the answer to your question is companies will stop investing that money. I can say that my parent company, Union Carbide, is very definitely questioning their involvement in electronic processing materials, and the reason for that is such the lack of return on investment in a near-term time frame. So by default, then, in fact what happens is we exit markets and lose the infrastructure in which to be competitive.

Mr. MINETA. Well, then, Mr. Coder, why is it that our companies take that view, and yet European and Japanese companies don't seem to? They somehow have this "patient capital," are willing to stick in there for the long term, part of it because of maybe vertical integration, but why is that? I mean, we have vertical integration in a sense, as you've indicated about your parent company. Allied-Signal has the same thing, but has deep pockets. Why is it that we're not willing to hang in there for that longer term?

Mr. CODER. I can't give you the answer in terms of Japan versus the U.S., but I can say from the standpoint of the U.S., it is the bottom line and the drive to the bottom line on a quarterly basis. We do not take a long-term view in terms of doing business in terms of putting the infrastructure there to look at growing businesses over a period of time.

The other thing that has happened is that there is a tremendous number of opportunities, and so you compare those opportunities in terms of return on investment, and the very costly areas, such as semiconductor materials, you can get a better return in another area, so we elect not to pursue that area and go where the return is better. And it's a short-term view, but it basically says that you watch a specific industry or market proceed offshore.

Mr. MINETA. So we let the universities do the novel research for materials. Who do we turn to for materials processing and synthesis if it's not the private sector? Is it DARPA? Is it NASA, given our Federal budget? You know, even that's starting to dry up. So where are we going to be 15 or 20 years from now, when someone is going to be sitting here in Chairman Valentine's spot saying, "What were they thinking about? What were they doing 20 years ago?"

Dr. Good?

Dr. GOOD. Yes, let me make a comment. I don't think it's quite as grim as that. I don't think the industry has been quite as negligent in hanging in as has been said. It is true that we have a major push for quarterly returns and all that sort of thing, but if you look at what the industry did over the last 10 years, beginning about 1980—now, it's true that they backed away from a fair amount of R&D in the late 1970s, but beginning about 1980, they have gone up more than inflation in R&D every year. If you look at what they did in the current recession, which is pretty tough out there right now, particularly if you happen to have an automotive sector, many of them in this recession did not do as they had done in past where they went in and chopped out R&D. They have not done that this round, which is an interesting statement, I think, and I think we really ought to look at that.

There are some people who are willing to stay for the long term. The issue with respect to the chemicals that Mr. Coder is talking about is the fact that Carbide has already put an enormous amount of money in that hole. The problem is they've spent the money, and they're not getting the return today. That's correct. But what people don't understand is there's a heck of a lot of investment there on which they're getting no return. That's the question. That's the issue.

So there is, I think, two things that have happened over the last five years. The manufacturing quality in the United States has truly turned around, and I think most of you who look at that will agree, and most of us would agree that that is true. Lots of effort, lots of time, lots of restructuring, lots of getting rid of middle management that was not productive—all of those things have truly happened.

The competition in the world today is really tough. There are a lot of folks out there who are very good, and it's not just the Japanese. The Europeans are getting back in the bowl where they are very good, the Asians are very good, the Koreans are very good. It's a very competitive world. And so the issue is that you can't any longer do well by just getting by in our own market. You have to be good enough to compete worldwide, and the issue is how do we do that, and if you want our companies in our country to participate in that, how do we give them at least a reasonable fighting chance?

One is the trade issue. You know about our Metglas program with the Japanese. We finally managed that, but it was with a lot of work and effort, and who knows whether they'll abide by it? So the trade issues are important. We need at least a level playing field, and we ought to be at least able to peddle anywhere else that we let people peddle here.

Secondly, we do have to look at what the government structure does. I was in Europe last week and held a technology conference for our people in Europe. We have a fairly sizable European operation, and we had the people from the European Community came and they talked about what they are in the process of doing to try to stimulate industry and commercialization within Europe. And they've put together what they call this framework program, and they're spending of the order of $6 billion to $10 billion a year to have collaborative programs that you can only play in if you're part of the European scene. Well, we're going to try to play in that, because if we can learn something from them, I can use it in both directions.

So the issue here is that the world has changed in the sense that we're not just competing with ourselves in the United States. When that was the case and this was the biggest market and that's where we sold, we could set rules and regulations that regulated all of us and kept us from doing the consumer in. As was pointed out earlier today, the consumer is not going to get done in anymore, because if we don't make it at a price, somebody else from outside will bring it here and sell it at a price.

So the issue is how do we provide some incentives, and how do we provide an infrastructure which allows us to be competitive? And there's no question that things like the DOD programs, where

we have been able to get advanced technologies off the ground and started, have been extremely valuable. I don't see any reason why we couldn't utilize—we're spending a lot of money in the Department of Energy today. Why couldn't those programs be focused on new technology for new energy industries and do them the same as we've done with the Defense Department kinds of programs?

Mr. MINETA. You've hit on an issue that I'm interested in, and that is maybe those very same companies don't have the capital to now go to the next step of commercialization, and what I have asked and done is that in the Advanced Technology Program of the Department of Commerce, within NIST, we have a Commercialization Loan Program, because we're good at R&D, and those small companies that have done that R&D may not have the capital then to commercialize what they've come up with.

And what I'm saying is let's take a little piece of that ATP program, put it in NIST, and make it a Commercialization Loan Program to give them that little incentive and the "patient capital" that has been mentioned here to be able to do that, and maybe we can take that, whether it's in DOE or in some other aspect of our Federal bureaucracy, where companies have done this kind of R&D work but need now something for making it commercially feasible.

So I'm hoping that this amendment that I got into our bill will be able to survive all the way through, because we're not really picking winners and losers in that. What we're saying is, "Look, we want to have a level playing field, and we want to create the environment that allows industry to do what they do best, and that's to compete and win."

Dr. GOOD. And I'm sure we're competent to do that.

Mr. MINETA. Bill? Mr. Reed?

Mr. REED. I'd just like to make a couple of comments.

Mr. MINETA. Mr. Chairman, let me just interrupt.

Mr. Reed, as you know—I really appreciate the fact that he is here, but his industry and he himself has just been a tremendous resource in terms of this push on what has to be done, and in terms of the semiconductor industry, he is in a very important piece of it. They manufacture the equipment that makes the wafers and all the other things that go into the semiconductor field, whether it's the materials or the equipment itself.

And so SEMI is a very important business. Their annual industrial exhibit gets bigger, but it's also, I think—just looking at the companies that are there, we see a lot more of the foreign companies coming in because of the nature of their development.

Bill, I'm sorry. Go ahead.

Mr. REED. That's okay.

In a recent survey, I think it was about 18 months ago, we did an analysis of how much money our small companies—and they are small; it's an industry of small venture capital, if you will—were spending on R&D, and this averaged 18 percent on gross sales, which is, you know, probably more than one and a half times what anyone else would spend. This kind of an investment enables us to compete in Japan, enables us to compete in Korea and Taiwan, where the industry is moving, but we need some relief. We need some tax relief on those huge investments for a small company.

Mr. MINETA. Let me ask on that R&D, should that be targeted? I mean, instead of just saying R&D—I mean, I support a capital gains. I don't like capital gains for the owner of a horse, I don't like capital gains for the owner of art goods, and so capital gains to me is okay, but how is it going to be used? Capital gains for the owner of that horse benefits that individual. It doesn't create another job. It may create stuff to shovel, you've got to shovel maybe, but that doesn't benefit society. We have experience with enough of that here in D.C.

[Laughter.]

Mr. MINETA. But it seems to me that even with R&D tax credits, instead of just saying, "Yes, we need R&D tax credits," maybe we need R&D tax credits that will give us what we're really driving at, that will give us maybe, you know, in terms of materials processing and synthesis and these other areas where we want that kind of emphasis.

Mr. REED. Can we say "directed" instead of "targeted"?

Mr. MINETA. Absolutely. Sure.

[Laughter.]

Mr. REED. It carries an implication which I don't think we want to get ourselves into.

Mr. MINETA. Sure. Okay.

Mr. REED. No, I'm just teasing a little bit.

Mr. MINETA. Well, it's like the word "industrial policy." We don't like to use the word "industrial policy," so we come up with—what's this phrase now we use? "Generic pre-competitive technology."

Mr. VALENTINE. That's a California word.

[Laughter.]

Mr. MINETA. Oh, no, no. That's an OMB phrase, Mr. Chairman, because they don't like the word "industrial policy," so we come up with this "precompetitive technology" or whatever it is.

Mr. REED. It would be very helpful if we could do that, because, as you know, Congressman, the semiconductor equipment industry is very disjointed. The small companies work on individual pieces of equipment, and there's very little conversation between a piece of equipment that's in front of another piece of equipment, and there are certain aspects of our industry that need a little attention here in the United States. For other aspects, we do very well, and in some of the processing steps, the United States has the lead in Japan. We sell more of our product in Japan than the Japanese companies do. Others, we need some help.

Mr. MINETA. But, see, they're concentrating on your part of the business. They're concentrating on software now. You know, what they do, again, is to direct their resources to where they're going to get the most bang for the bucks, and, you know, we sort of do things like taking margarine and spreading it on a piece of bread. They don't shotgun, they rifle, and I'm afraid—and I think Mr. Hennessey was saying this last night from Allied—that Europe may become a fortress of its own.

What's going to happen with the Asian/Pacific Rim markets? If we establish a North American, Central American, South American free trade area, are we dividing the world into four market areas so that we're competing not as a country in a global atmos-

phere, but four major competitive areas competing against each other? And what happens at that point?

Well, all of you have been just very, very good in your testimony. I wish also that you could have sat in on that discussion last night. I think you could have enlivened the discussion as well as probably made you red from anger, because the Ambassador, I'm quite sure, invited us in for, as he said, a "frank discussion," but no one likes a skunk at a garden party, and we were very good guests, we ate the wonderful food, but, boy, I'll tell you, we sure shoved it down his throat in terms of—

Mr. VALENTINE. Mr. Chairman, I could say right now if you could arrange to have us invited, we'd show up.

[Laughter.]

Mr. MINETA. Well, again, Mr. Chairman, thank you for your indulgence of the five-minute rule during my questioning, and, again, I want to thank this very excellent panel for being here today.

Mr. VALENTINE. Let me say to you, Mr. Mineta, that we all understand and appreciate your contribution in this area, and I would like to, of course, thank the members of this panel, and I have one or two final questions. I am appreciative of the few rays of sunlight that have filtered through the dark clouds here when I missed some of these.

But, I mean, it seems to be a failure of American preeminence, except in certain isolated areas, almost everywhere one looks, from paving materials to food to rubber to optics to electronics, automobiles, shipbuilding, computers, fabrics, steel, shoes, motorcycles, and skis. I don't think that we will have adequately dealt with the problem unless we are willing to discuss all of the problems and where we don't have any sacred cows grazing out in the pasture.

So my kind of final shot is to ask you, lady and gentlemen, this question, if you would like to make a comment on the problems which are created by legislative initiatives in such areas as strike legislation that's pending before the Congress. Congress attempts always, I think, to balance the equities. It does more so than people in the country generally would like to give politicians credit for, and there are many in Congress who feel that American labor requires the protection of the legislation which I'm talking about.

Would any of you care to comment on what that type of legislation might do to American competitiveness? That is to say that if American laborers are able to strike and stay out for a week, two weeks, three weeks, four weeks, or however long and demand their jobs back as a matter of legislative rights. Does anybody care to comment on how the passage of that legislation by the Congress might affect what we are here talking about?

[No response.]

Mr. VALENTINE. Would the panel care to discuss in any further detail, either here or in writing, really what the quality of American education does to the equation? What the morale factor of American laborers and indeed the impact on the American work force when it is disclosed that some industries that say they can't raise wages, it's determined that they pay their chief executive officers millions and millions of dollars? There's one as high as $60 million.

If any of you have any comments that you'd like to make on that. If there are any here who are paid that much money, we'll excuse you not from the table, but from any comments.

[Laughter.]

Mr. MINETA. Mr. Chairman, as I recall, the highest paid under the Forbes review was the chairman of Toys 'R' Us, so maybe that tells us a little something about where we are.

[Laughter.]

Mr. VALENTINE. Well, if you want to slip a little personal letter under my door sometime, feel free to do so, unsigned.

[Laughter.]

Mr. VALENTINE. Thank you all very much. The record will be open for 10 days if any of you have any supplemental statements you'd like to file with us. Thank you.

[Whereupon, at 12:01 p.m., the subcommittee was adjourned, to reconvene at the call of the Chair.]

APPENDIX I

CHARTER FOR A HEARING ON

CRITICAL TECHNOLOGIES - MATERIALS
JUNE 11, 1991

Materials and materials processing are top priority critical technologies for the United States' international competitiveness. The future of the aerospace, electronics, automotive and medical industries all rely on the development of new and superior materials. The production of these new materials depends on efficient synthesis and processing techniques, creating advanced ceramic, polymer, composite and alloy materials with a wide range of applications. In their report, "Gaining New Ground", the Council on Competitiveness identified several areas in materials and processing technologies where the U.S. competitive position was eroding, or weak, or lost in their opinion. The National Critical Technologies Panel of the Office of Science and Technology Policy came to similar conclusions about materials in their 1991 report. This situation has led to the decline of numerous U.S. industries, and promises to erode market share further if the trend is not reversed.

What can and what should the U.S. government do? One possible answer is based on the tremendous demand for new materials in defense applications. For example, hundreds of advanced materials were created in the B-2 bomber project alone. A new and vigorous policy that brings about a productive partnership between federal laboratories and industry may be needed. Collaboration on research decisions to fund programs more relevant to industry and facilitating technology transfer of materials already created may help restore the competitiveness of many U.S. industries. Another proposal is the establishment of a more favorable environment for new and innovative materials and processing technologies that can be introduced into products and manufacturing. Can new legislation or policy remove impediments to the commercialization process? Finally, the government may have no role once technologies leave the development laboratory, and should stay out of the commercialization process.

The most effective role of government is not clear. Several authoritative witnesses are to make their recommendations with regard to government roles and/or legislation that will accelerate the passage from discovery to product of new materials and processes in the interest of enhancing the U.S. competitive advantage.

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ISSUES:

1. What is the current status of U.S. technology in the materials field? chemicals? ceramics? etc. What will the consequences be of foreign domination of this technology? Are there unique qualities to certain materials that require special involvement by the federal labs or government?

2. What are the impediments to the development and commercialization of new materials? How can the government help?

3. What are the benefits and risks to joint ventures between industry and the federal laboratories? Is this the most effective way the government can help? Are CRADAs (cooperative research and development agreements) helpful to materials technologies?

4. What constitutes a favorable environment for materials development and actual use in production? Do current standards enhance or limit such development? What is the role of patent and intellectual property enforcement?

5. If the government adopted a "hands-off" policy in this area, what would be the result?

APPENDIX II

FMS

FEDERATION OF MATERIALS SOCIETIES

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H. Nathanson (IEEE)
R. E. Hicks (SHM)
R. Babcock (NACE)
J. B. Darby (TMS)

MEMBERS
American Association for Crystal Growth
The American Ceramic Society, Inc.
American Chemical Society
American Institute of Chemical Engineers
American Society of Mechanical Engineers
ASM International
ASTM
American Welding Society
The Electrochemical Society, Inc.
Institute of Electrical & Electronic Engineers, Inc.
International Society for Hybrid Microelectronics
National Association of Corrosion Engineers
TMS

June 20, 1991

The Honorable Tim Valentine, Chairman
Subcommittee on Technology and Competitiveness
Committee on Science, Space and Technology
B374 Rayburn House Office Building
Washington, DC 20510

Dear Mr. Valentine:

In response to the invitation you issued at the June 11, 1991, hearings on advanced materials as critical technologies, the Federation of Materials Societies is pleased to provide a statement for the hearing record.

As you know, Mr. Chairman, FMS is a consortium of technical, professional, and educational societies and associations whose constituents include scientists, engineers, and other professionals active in the areas of materials research and development, processing, manufacturing, recovery, resource availability and policy. The Federation's mission is to identify materials issues and opportunities and to provide the most effective mechanism for cooperative interaction among academia, industry, government, the general public, and its member societies.

One of our major activities is sponsoring the Biennial Conferences on National Materials Policy. As you will recall, we presented the findings of the 11th Biennial Conference to the Congressional Caucus on Advanced Materials on September 26, 1990. The purpose of the Biennial Conferences is to provide a forum for members of the materials community and policy makers in government, industry and academia to work together in a collaborative effort to maintain focus on the importance of the development of a national materials policy; work toward the development of a national materials policy which is responsive to the continually changing national environment; build and demonstrate a consensus among the materials community on the essential elements of a national materials policy; and convey to national policy makers key perspectives developed by participants in the Conference.

We are requesting that this letter and the enclosed documents be placed in the hearing record:

1) The Action Agenda from the 11th Biennia Conference, held in June 1990, which explored the role of processing in the health of the materials industry; and

2) Workshop reports from the 10th Biennial Conference held in

June 1988, which explored several of the industries which were included in your June 11 hearings.

Both of these Biennial Conferences explored the specific issues with which your Subcommittee is struggling. The recommendations which were generated in the workshops address many of the questions which the Subcommittee members asked the panel of witnesses.

Both Biennial Conferences addressed the recurring concern of industry for a regulatory environment that allows businesses to justify the high cost of the development work needed to bridge between basic research and invention - an area in which the U.S. continues to lead - to full commercialization of those discoveries and inventions. There are several specific recommendations enumerated in the enclosed material which should form the foundation for action by Congress.

Participants in the FMS conferences recognize that a great deal of progress has been made in the last several years and that laws have been passed or interpretations changed so that a better climate exists today. Nonetheless, their consensus is that there is room for and a need for continued forward movement by clarification of those positive actions such as the encouragement of both horizontal and vertical consortia for the purpose not only of generic research but also of the pre-commercial development needed to bring a new product or process to a cost-effective state of commercial readiness. Similarly, there remains the need for new legislation in areas such as operative, workable protection of process patents, improved Federal support of processing research at the university level, expanded tax credits for not only basic research but also development and manufacturing technology, etc.

We are pleased to have the opportunity to place this information in the hearing record for consideration by the Subcommittee in its efforts to strengthen the competitive position of U.S. industry. FMS is available for consultation and testimony as may be required. Contact may be made through our Executive Director, Betsy Houston.

Sincerely,

James A. Ford

James A. Ford
Chairman, Government Liaison Committee

DEVELOPING A VISION FOR MATERIALS PROCESSING IN THE 1990'S: THE ROLE OF NATIONAL POLICY

ACTION AGENDA
developed by

11TH BIENNIAL CONFERENCE
ON NATIONAL MATERIALS POLICY

Sponsored by the
FEDERATION OF MATERIALS SOCIETIES

Over 80 leading industrial managers, university educators, and government policy managers met in Williamsburg, Virginia, June 11-14, 1990 to address this question:

How can the U.S. do materials processing more effectively, from research and development through to the factory floor?

Conference participants determined that national competitiveness in materials is a cornerstone of U.S. industrial competitiveness and requires a quantum step improvement in U.S. competence in materials processing. They agreed that understanding the critical nature of materials processing, transferring new processes to the factory and developing high quality, high yield, cost effective processes must be a cooperative enterprise among government, industry and universities. While under pressures of the bottom line, the U.S. materials related industries, government agencies and universities alike will have to find a means to take a longer range view - a vision - of the future.

Speakers from all facets of the materials community addressed the problems and opportunities in materials processing from the point of view of industry, government and academia. Then conference participants broke into four workshops to develop their vision. The workshop recommendations comprise an "action agenda" which is summarized in this pamphlet by Conference Chairman R.A. Laudise (Director, Research Laboratory for Materials and Processing, AT&T Bell Laboratories). Proceedings of the conference, including texts of keynoters and full reports of the workshops, are available at US $45.00 per copy from the address below.

The Biennial Conferences on National Materials Policy are sponsored by the Federation of Materials Societies, a consortium of technical, professional, and educational societies and associations whose constituencies include scientists, engineers, and other professionals active in the areas of materials research and development, processing, manufacturing, recovery, resource availability and policy. The Federation's mission is to identify materials issues and opportunities and to provide the most effective mechanism for cooperative interaction among academia, industry, government, the general public, and its member societies: the American Association for Crystal Growth, American Ceramic Society, American Chemical Society, American Institute of Chemical Engineers, American Society of Mechanical Engineers, American Welding Society, ASM International, ASTM, The Electrochemical Society, Institute of Electrical and Electronics Engineers, International Society for Hybrid Microelectronics, National Association of Corrosion Engineers, and TMS.

For further information, and to order Conference proceedings, contact:

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EDUCATION FOR NATIONAL PROCESSING EFFICIENCY

A new generation of educated processing scientists and processing engineers is required and the scope and depth of processing science and engineering knowledge must be very considerably enlarged. These responsibilities lie particularly with the universities but they will require encouragement and financing from the government and tighter collaboration with industry to ensure relevance and provide test beds in real factories where students can learn hands-on processing. To improve processing education and enlarge the base and relevance of processing knowledge through research and the collation of known results, we recommend:

1. **Curriculum reform in Materials Science and Engineering departments to provide core courses in processing literacy for all MS&E graduates beginning at the B.S. level.** The trade-offs between focusing on disciplinary cross-cutting processing offerings and reflecting the differences in processing problems for metals, ceramics, polymers, electronic materials and other materials classes will probably require both general and materials specific courses in processing. We also recommend organized course offerings which allow students to graduate at the M.S. and Ph.D. levels in MS&E with a specialization in processing science/engineering. The University Materials Council is an appropriate body to initiate these reforms.

2. **Tighter coupling of processing MS&E education to real world processing in factories through cooperative student assignments, internships and the establishment of materials processing practice schools.** One such school should be established as soon as possible with seed money provided from industry and government. Additional bridges to industry should be built by the systematic recruitment of industrial people for permanent and adjunct academic appointments and by institutional arrangements which make faculty sabbaticals in industry commonplace. A reasonable goal is that 20 percent of academic sabbaticals in MS&E be industrial.

3. **Increased and closer ties among all disciplines in materials science and engineering.** Materials science and engineering and especially materials processing clearly are interdisciplinary. Chemical engineering should serve as a model for creating the field of processing engineering. Physical chemistry can provide the basis for processing understanding. Closer ties between these fields and MS&E are vital, through joint appointments, inter-departmental research, the use of relevant course material from these departments in MS&E curricula, and faculty appointments of chemical engineers and physical chemists to MS&E departments. Care should be taken to build on the disciplinary strengths in MS&E departments in ceramics, metallurgy, polymers, electronic materials, etc. Indeed, it is quite logical that particular departments will focus on the materials class (or classes) where they have strengths.

4. **Ensure that the relevant science in materials processing is codified and used in teaching.** To this end, we recommend that monograph and text writing be explicitly rewarded in tenure decisions and that NSF commission at least a half dozen targeted processing texts via appropriate grants.

5. **A 10 percent per year increase in constant dollar NSF support for Principal Investigator materials research for three years.** In an effort to increase relevance and generate group activities, fundamental science in materials (and the other physical sciences) must not receive short shrift, and the decline in PI support must be arrested.

INTERNATIONAL COMPETITIVENESS

Industry is the cockpit of international competitiveness and is where the battle for processing effectiveness will be won or lost. Industrial processing improvements will be achieved both with changes in managerial attitudes and with organizational modifications. Our recommendations address both:

6. **Apply quality methods to improve processing.** Industry has rediscovered the quality concepts of W. Edward Demming and his modern disciples and is applying

them with a vengeance to assembly operations but not so thoroughly to processing. Procedures ranging from statistical quality control and analysis of process variables to identify the steps in complex processes which leverage yield, to systematic examination for the root causes of yield problems (be they bad designs, bad materials choices or the use of non-robust processes) can produce great dividends. Quality concepts should be applied to customer satisfaction and internal human process optimization. The idea that a factor of 10 improvement is normal and required to stay in business has been amply demonstrated in the assembly and service industries. We urge concerted quality activities in the processing industry and the introduction of quality concepts and methodology in student education.

7. **Develop an attitude of partnership between customers and suppliers.** As integrated manufacturing in materials becomes less common in the U.S., large device and systems customers must adopt a different attitude toward their merchant materials suppliers - an attitude of partnership. Here, business people and the legal profession can make a great contribution to competitiveness. They must help the materials managers in industry to redefine supplier/customer legal relationships so that more of the downstream benefits which material produces for the device and systems manufacturer can flow back to the supplier. In return, the supplier should give a particular advantage to his preferred customer, via arrangements for first availability, best material, cheapest material, etc. Creative purchasing contracts, part ownership of merchant suppliers by customers, etc., are all possible mechanisms. Lawyers, accountants, and MBA's motivated to improve U.S. competitiveness by helping create truly cooperative vendor/purchaser arrangements should be encouraged to help processing industry management create new relationships.

8. **Establish industry/university consortia based on processing.** The existing knowledge base in processing is not being adequately applied in the factory and is not being enlarged rapidly enough to move processing toward the sophistication required by U.S. industry. Therefore, we must try to use U.S. science and engineering - especially at the universities - to out-think them. Industry must interact more strongly with universities in order to survive.

GOVERNMENT ROLE IN FOSTERING PROCESSING SCIENCE, TECHNOLOGY AND COMPETITIVENESS

The Federal government historically has been the principal patron of basic science in the U.S., and in an era of industrial competitiveness it must recognize that it has a responsibility for nucleating precompetitive activities, providing an environment where industrial competition in materials processing can succeed and assuring the health of engineering as well as science. To these ends, we recommend:

9. **Changes in fiscal policies to encourage "patient capital."** The Federal government must change with words and deeds both in the Legislative and the Executive Branch the fiscal policies which result in an environment where investments in research, development and technology transfer require a payback time half that of our competition. In the absence of fiscal reform, following our other recommendations would be like rearranging the deck chairs on the Titanic.

10. **Better coordination of government policy on materials.** We are pleased by the recent focus of the Office of Science and Technology Policy on materials and the formation in OSTP of the President's Council of Advisors on Science and Technology which has a new policy emphasis directed toward processing. We urge follow-through and development of overall Federal materials priorities.

11. **More effective harnessing of National Laboratories to materials priorities.** The National Laboratories are a national asset, comprise a substantial fraction of our strength in materials, and consume a substantial fraction of government materials spending. We recommend that each lab generate a simple mission statement for its materials activities. The mission statements should not

be generalized; laboratory mission statements should not be overlapping, and they should include outputs which are relevant to industry. Laboratories should be judged against their mission statements. We recommend designating two or three national laboratories as lead laboratories in non-overlapping areas of materials processing. We suggest the strong encouragement of national lab partnering with nearby universities and industrial organizations relevant to their strengths. We recommend an NRC study of processing at the national laboratories to aid in priority setting.

12. **A focused, Federal program to provide seed money for pilot processing consortia.** We recommend that two to three such consortia be established via a matching funds mechanism.

13. **Wider dissemination of information on state and regional initiatives in MS&E.** State governments lately are assuming a role in leveraging university activities to improve local industrial competitiveness. Processing can provide the key to local industrial competitiveness and should play a special role in state initiatives. Little information exchange between states and regions is taking place and not enough emphasis on processing is present in some state programs. We recommend appropriate society sponsorship of a workshop with the working title "State and Regional Initiatives and Opportunities for Materials Science and Engineering."

COOPERATIVE VENTURES

Cooperative activities will be key to making finite human and monetary resources go further, and when industry is a partner they are the best way to effect factory competitiveness. To improve the climate for cooperative activities, partnerships and consortia and to see to it that they increase, we recommend:

14. **More synergistic materials supplier/materials user relationships.** Merchant suppliers and entrepreneurial materials providers must reap more of the benefits which their customers gain at the device and systems level. Materials suppliers must be willing to offer unique benefits in the form of first access to leading edge materials, priority supplies, lower costs, etc., to customers willing to enter into cooperative arrangements with them. Creative purchase contracts and cooperative supplier/purchaser programs including joint investment in new materials facilities must become common. Entirely new mechanisms for assuring the health and deriving the benefits of U.S. merchant materials suppliers must be invented.

15. **Establishment of more industrial consortia, particularly in the area of process equipment.** SEMATECH is a useful model. We urge the creation of an industry/government/university committee to look into appropriate venue, size and programs for such consortia.

16. **Better utilization of cost-free procedures for encouraging industry/academia cooperation.** We urge more adjunct professor appointments from industry, joint postdoctoral appointments, interns, sabbaticals, etc.

17. **Establishment of Industry/University Cooperative Research Centers.** We recommend funding of at least five centers devoted to metals, ceramics, polymers, electronic materials, composites, and other materials classes.

THE MATERIALS COMMUNITY

"Physician, cure thyself!" is a not unrealistic directive for the materials community. Much can be done by the community itself to improve processing and assure its contribution to competitiveness. In particular, we suggest that societies should encourage processing excellence and processing prestige by appropriate national and international prizes in processing science and engineering, especially for factory aspects of processing. National society symposia on processing subjects, commissioning of special processing articles for journals and, where appropriate, special processing issues are also recommended.

AN AGENDA FOR MATERIAL CHANGE

CREATING A MATERIALS FUTURE: TRANSLATING SCIENTIFIC LEADERSHIP INTO COMMERCIAL ADVANTAGE

developed by

10th Biennial Conference on National Materials Policy

FMS

WORKSHOP SUMMARY

HIGH TEMPERATURE MATERIALS

INTRODUCTION

The events of the 1970's and 1980's have demonstrated the critical impact of advanced high temperature structural materials on U.S. industrial competitiveness and national defense. Typically, the importance of these materials is highly leveraged because they fulfill key functions in the overall performance and value of the end system in which they are employed. Successful track records of U.S. innovation in advanced materials include the research, development and commercialization of titanium alloys and superalloys for high temperature service. However, in recent years, intensifying foreign competitive pressures threaten the U.S. predominace in these areas of traditional strength. Moreover, in other areas, such as advanced composites, intermetallic compounds and ceramics, well planned foreign programs with long term funding commitments pose a serious threat to U.S. competitiveness in these future generation materials.

In order for the U.S. to maintain its competitive position in advanced materials and in critical technologies dependent upon them, the causes of the problems must be diagnosed and steps taken to rectify them.

Several central issues including the following need to be addressed. For example, is the U.S. limited by:

- Invention of new or significantly improved materials?
- Conceptualization and development of new products from these materials?
- Manufacture/commercialization of these materials and products?
- Appropriate cooperative/synergistic roles for industry, government and academia?

The consensus of the workshop was that an integrated approach with commitment and continuity is required by industry, government and academia. The competitiveness of U.S. scientific and engineering research and inventiveness remains high, although U.S. activity as a percentage of total work activity has declined with the increase of research and development efforts in Japan, Europe and developing countries. In the two subsequent steps of the innovation process, precommercial development and manufacturing, the U.S. needs to make substantial improvements in order to compete successfully. A number of critical issues/needs were identified at the workshop which are addressed below with appropriate roles suggested for industry, government and academia. These include:

- A committed, long-term approach to the innovation of advanced materials, with continuity and staying power.
- Increased emphasis on commercial technologies, in addition to traditional emphasis on military technologies.
- Strengthen market/technology pull approach to advanced materials innovation.
- Provide incentives and remove barriers to advanced materials developmnet related to market identification, intellectual property and investment in manufacturing.
- Address the entire infrastructure required for commercial manufacture of advanced materials, including process equipment for their manufacture as well as the end use system incorporating the advanced material component.

HIGH TEMPERATURE MATERIALS VIS A VIS "NEWER" (ELECTRONIC, OPTICAL, MAGNETIC) MATERIALS

The general public and many key government people are unaware of the critical importance of advanced structural materials to high technology manufactured goods. For example, entire industries such as air, land and sea transportation, space, power generation and chemical processing are highly dependent on high strength and/or high temperature materials. In some cases, such as aircraft engines, further significant improvement in performance or cost of the product will require specific advancements in material capability.

To some extent, this disparity in awareness is believed to be due to the fact that "figure of merit" may be easier to understand for the "newer" materials. The benefits of faster computer calculations and clearer telephone communications are more readily understood than an increase of, say, 100°F in stress rupture capability or oxidation resistance in a structural material.

One of the results of the lack of appreciation for the importance of high temperature structural materials within industry and government has been inconsistent funding support over time. The nature of research and development in this area is such that extensive processing, testing and characterization is required. Scale-up beyond the laboratory stage depends on expensive capital equipment and systematic processing trials. Therefore, substantial inefficiencies are encountered in attempts to advance the state-of-the-art of structural materials technology when programs are run on an intermittent or "crash" basis.

The following actions are recommended to facilitate more informed and timely decisions by industrial and government managers:

- Design and material engineers within industry and government should refine expressions of "figure of merit" for high temperature structural materials which would be more readily understood by non-technical personnel. This would begin to allow a value to be assigned to the technology content of a product.
- Technical societies should reach beyond their membership to the general public (e.g., via press releases) in describing important needs and progress in structural materials research and development and commercialization.
- Similarly, selected materials societies (e.g., FMS) should expand the scope and increase the intensity of communications to government decision makers via reports, briefings, and documentary tapes. Examples in this regard include NASA Lewis briefing charts, a recent AIAA report and a report prepared by the Office of Technology Assessment (OTA) which was requested by the Senate Committee on Commerce, Science and Transportation.

PROTECTION OF INTELLECTUAL PROPERTIES

For private industry, the ability to protect intellectual properties forms a cornerstone of the incentive to develop and implement new technologies. A need was identified for improved means to protect intellectual property in two specific areas:

1. **Enforceability of Process Patents** There is a general need to improve on the means to enforce process patents, both within the U.S. and, more particularly, in regard to the infringement of U.S. process patents in the production of goods in other countries for export to the U.S. In this latter instance, two

WORKSHOP SUMMARY

HIGH TEMPERATURE SUPERCONDUCTING MATERIALS

Advanced materials will be vital for the American economy in the immediate future. The world has come through the Stone Age, Bronze Age, Ivory Age, Steel Age and Semiconductor Age. Perhaps we are now at the threshold of the Superconductor Age. Certainly we are in the Advanced Materials Age.

A key element in the challenge of superconducting materials is to understand that it requires a strong multidisciplinary effort including new material synthesis, materials processing, the most advanced microstructural and electromagnetic characterizations and, most of all, the development of an understanding integrating of all of the above. These goals require long-term, consistent support of superconductivity in both its low temperature and high temperature manifestations.

I. TECHNOLOGY ISSUES

What are the technology hurdles limiting the:

1. Invention of New Materials?
   a. The U.S. does not have the technology base (trained researchers) to develop new materials. In particular, there is a lack of strong research groups in the universities pursuing new materials development.
   b. There is a lack of commitment to search for new materials over the long term.
2. Significantly Improved Materials?
   a. Synthesis and processing facilities are inadequate in U.S. universities and national jobs.
   b. There are deficiencies in the characterization facilities and commitment to support these facilities in U.S. universities. Excellent facilities exist in some national laboratories, universities and industries. Small businesses are lacking these facilities.
   c. Most instrumentation is made abroad. Therefore, refinements and improvements first benefit those countries where the instruments are manufactured (technology driven science).
   d. There is a need to continue developing theory and modeling capabilities to guide the development of new materials.
3. Conceptualization and development of new products from materials?
   a. The development of new products using high temperature superconductors is now hampered by their properties.
   b. Limited product development should be pursued while research is directed at improving the superconducting properties. (This approach may lead to earlier commercialization.) Ongoing development of traditional (low temperature) superconductors should be continued to find new applications.
4. Manufacture/commercialization of these products and materials?
   a. These activities are limited by the basic material properties of high temperature superconductors. More emphasis needs to be put on manufactur-

DIAMOND FILM SCIENCE AND TECHNOLOGY

Abstract

This White Paper presents the facts on this very major technological advance—the ability to deposit crystalline diamond films on virtually any substrate—and the status of U.S. R&D compared to Japan and the USSR.

Diamond films form the prototypical example of an "enabling technology." Based on a Soviet discovery, Japanese industry has a 4-5 year head start. The U.S. has no broad agency interest: no response by OSTP, no study by OTA. This White Paper is a call to action in a coordinated program.

A Startling Comparison Highlights the Issue

The United States Government—through several Federal agencies—is spending somewhere in the neighborhood of $150 million a year on high T_c superconductor research.

The same government is spending about $10 million a year on diamond film research. Awareness by the scientific community of high T_c superconductivity and diamond films occurred within a year of each other.

Yet the reasonably projected potential impact on technology and employment, civilian and defense, in the 10-20-year time frame is say two orders of magnitude higher for diamond films than for high T_c superconductivity. (No consensual analysis even by superconductor enthusiasts any longer claims differently.)

It is not difficult to see how the general public, including scientists in other fields, and the Congress whose main opinion-forming vehicles are the mass media, could have supported such an order of magnitude distortion of priorities. But it is difficult to understand how the science policy-making apparatus, from the OSTP to the separate agencies to the Academy, has ignored this apparent distortion of priorities. Certainly there is no other technology-driven policy issue of similar magnitude on the horizon. By whatever rational, self-consistent standards one makes R&D budget allocations it is obvious that diamond film research in the U.S. is being neglected by an order of magnitude. This is the thesis of this White Paper, addressed to both the Executive and Legislative sides.

Historical Background

The attainment of the high temperature, high pressure synthesis of diamond in the mid-fifties by two or three groups was a historic benchmark in humanity's ability to duplicate nature. Its subsequent commercialization by G.E. and then by de Beers led to a substantial stable U.S. industry in synthetic grinding materials. It also unfortunately dampened the interest in alternative routes to diamond synthesis.

Yet sporadic interest in vapor-derived diamonds continued at Union Carbide and Case Western Reserve University. But it was in the Institute of Physical Chemistry in Moscow that

specific procedures are needed: (a) the right to rebuttable presumption of infringement to deter the import of such goods, and (b) the right to accrued damages from the date of initial importation.

2. **Revision of DOD-Mandated Technology Transfer** Procedures are needed to establish a better balance between two conflicting objectives. The first of these is related to the needs of the Department of Defense for competitive procurements of materials and systems and the sharing of technology with NATO allies. The second is related to the needs of U.S. industry to protect unique technological advantages. A review of DOD practices in this area is recommended, placing appropriate emphasis on incentives for industrial competitiveness and on U.S. competitiveness in world markets.

RATE OF DEVELOPMENT AND COMMERCIALIZATION OF ADVANCED HIGH TEMPERATURE STRUCTURAL MATERIALS

There is general concern that development and commercialization of materials in the U.S. is too slow and also too costly. Three broad but interrelated areas are seen as pacing issues in the rate of developing advanced materials to the point of commercialization:

1) Establishing and maintaining groups with great enough breadth and depth to constitute "critical mass."

2) Fostering the development of production technology.

3) Minimizing barriers, i.e., encouraging standardization and streamlined government regulations.

Establishing efforts with critical mass is most fundamental to developing advanced materials where the technical base is limited, e.g., ceramics and advanced composites. Such activities or groups are needed to enhance pre-competitive research and development activities and extend these into production technologies, e.g., via pooled resources, consortia or joint ventures. More comprehensive efforts are also important in enhancing up-front analytical work - i.e., establishing design criteria to guide both material process development and standardization. A key component of such groups is their interdisciplinary character. Specifically, disciplines such as mechanical and chemical engineering need to be included to bring the design and process technology capabilities, including the importance of the design of processing and manufacturing equipment. The establishment and maintenance of these activities will be enhanced by establishing a sustained government purchase commitment, e.g., under Title III of the Defense Production Act.

A related critical step is fostering the development of the necessary production technology. Critical needs here are:

1) Establish research support for production technology, including manufacturing. These have clearly not been glamour topics and hence have been considerably underfunded.

2) Address university curriculum issues to develop instruction in this area (driven in part by research support).

Effective research and development in this area is one of the driving forces for critical mass efforts since much of this work can only be effectively done if the scale of effort is above a certain size. Expanding government purchase commitments can also assist their development by providing income to support profit scale facilities. Two barriers to advanced materials development are the diversity of targets and increasing regulations.

Standardization of requirements, i.e., giving a limited number of rational specifications to be achieved, can make development efforts more efficient. Streamlining government regulations, e.g., time and effort to obtain pre-manufacturing notices, can also be very useful.

SUMMARY

Development and commercialization of advanced materials is a slow and often tedious process due to the inherent and often unkown (due to the lack of familiarity with modern manufacturing technology) risks involved in investing in the substantial capital equipment necessary in this industry.

The following recommendations offer a framework for lessening the initial uncertainty and reducing the burden of these risks:

1. **Government**
   a. Current regulations, policies and programs should be publicized and compliance with regulations should be streamlined:
      - Pre-investment purchase commitments
      - Defense Production Act (Title III) and the Defense Procurement Act
   b. Assure the rationality of pending legislation via careful assessment of impacts in U.S. and world markets, e.g., RCRA and HAZCOM.
   c. Advocate new policies/legislation, i.e., the importance and value of process/-manufacturing expertise should be emphasized in academia and industry.
   d. The cost of capitalization should be reduced:
      - Reduced interest rates
      - Tax benefits
      - Research and development capital should be expensed.

2. **Industry**
   a. "Figures of merit" for advanced, high temperature structural materials should be re-defined and communicated more clearly to government and academia.
   b. Promotion routes to top management positions through manufacturing/process disciplines should be emphasized.
   c. A mechanism should be set up (possibly using the SIC system) for the creation of a national materials database and standardization of testing.

3. **Academia**
   a. Courses (multidisciplinary) in this area should be encouraged and accredited (the constraints of ABET should be lessened).
   b. Additional research proposals for manufacturing technology development should be encouraged and funded.
   c. Mechanisms for increased exposure of students to industry (in addition to co-op programs) should be developed.

WORKSHOP SUMMARY

ELECTRONIC MATERIALS

INTRODUCTION

Electronic materials can be defined as materials of present and future interest for the production of electronic components and devices. Included are: semiconductors (including processed, integrated circuits), dielectrics, magnetics, piezoelectrics, optoelectrics, optical fibers, interconnection materials, single crystals, ceramics, glasses, and polymers. Electronic materials processing is essential to the manufacture and use of economically competitive products. Electronic materials represent a major economic segment, U.S. semiconductor shipments alone accounting for over $15 billion in 1986.

The U.S. has moved from a dominant world position in electronic materials in 1975 to clear loss of leadership in major segments of the industry today. For example, in Dynamic Random Access Memories (DRAMs), the U.S. share declined from 100 percent of the market in 1975 to less than 10 percent in 1988. While perhaps not as dramatic, the trend is similar in other areas as well.

Electronic materials are an enabling technology for large segments of the U.S. economy, including telecommunications, computers, industrial processing and energy management and use. Efficient production of these materials gives great competitive advantages and provides enhanced leveraging in the production of components, devices and systems. Hence, electronic materials must be considered strategic to U.S. competitiveness.

The U.S. has traditionally had and continues to have a strong position in the fundamental understanding of the relationship between chemical bonding, structure, and electronic properties. However, the U.S. in the past few years has become less effective in realizing commercial advantage from its scientific strengths in electronic materials. Moreover, the U.S. lacks adequate capabilities in the synthesis and discovery of new materials. More often than not new materials, such as III-V semiconductors and the recent high-temperature oxide superconductors have originally come from longstanding European research in this area.

ACADEMIA

The University Setting

In addition to education and indeed to assure the quality of advanced education, an essential role of the university is to carry on high quality research which is widely available in the reviewed journals. University research can contribute to important practical payoffs especially if it is carefully targeted. Faculty consulting with industry, and other academic-industrial interactions, are the key to identifying appropriate research. Federal funding that better provides research continuity is also essential. However, NSF's support of new Engineering Research Centers (ERCs) has not had a primary focus or long-term commitment in the materials area, in spite of the increased recognition of the importance of materials.

In the university curriculum, there is a tradeoff made between breadth and depth. Should students concentrate in core areas or be trained with a more integrated perspective on the whole of materials science? Should the university do the basic, fundamental training in a core area and leave the integration and synthesis to "on the job" training? Do we need a five-year curriculum? These and other questions arise in looking at university programs.

There are no simple answers to these questions. Indeed, a variety of programs with differer styles and emphasis offered by the various universities is one effective response. The marke i.e., the choices students make can serve to enforce efficiency in the offerings. Neverthele most customers for students (primarily industry) feel that at the undergraduate level basic must be emphasized. Work-study is an underutilized mechanism for introducing reality int the education process. In addition, graduate education should produce a person fitted fc independent, creative scholarly research.

In terms of coordinating the activities of institutions, there are frequent instances of undesir able duplication of facilities among universities, and sometimes of insufficient technic competence to support them. It is not necessary for every professor to have his own persona facility. Rather, for interdisciplinary activities like electronic materials, it may sometime be effective to build a few centers with full state-of-the-art equipment. Furthermore, fo the present financial base the number of accredited, degree-granting institutions may b too large. With the stagnation of the defense budget, 6.1 research funding is likely to fall It must be noted, however, that basic 6.1 funding is such a small part of the nation's tota spending that even under a contracting budget, basic funding for materials should and mus be expanded dramatically.

Industry-University Interaction

For reasons of both compensation and professional recognition, new entrants are not attracte to processing as an occupation. Nor is the educational system primarily geared to make pro cessing a desirable path. The historical experience of chemical engineering is an exception however, and materials should use chemical engineering as a model to become proces oriented.

It would be useful to compile a list of electronic materials industry-university partnerships For example, programs are now in place on which experimental work for the master's degre can be done in industry. In compiling the list, care should be taken to focus not just on the experiences of the elite institutions, but more broadly on a variety of university settings In general, moving people is key to effective technology transfer, and incentives need tc be put in place to encourage such things as university sabbaticals for industry or industry. post graduate positions. Continuing education funded by industry might also be targetec to manufacturing.

Public Awareness - Grassroots Approach

Science lectures for the public, increased use of media, even the experience of a best-selling Japanese comic book on superconductivity are useful mechanisms to inform and attract young people. Here, the education committees of professional societies, including IEEE, FMS, etc., can play a major role. It should be noted that the launching of Sputnik and the crossing of the Atlantic by Lindbergh galvanized public atention, leading in part to focused federal funding for science and technology!

Recommendations

- Funding for basic research must be held at the present level to maintain our present strength in fundamental materials science.
- Interdisciplinary programs must be encouraged as they address many of the needs of materials, synthesis and processing.
- Voluntary coordination of research thrusts between universities would help to avoid

excessive duplication.

- Modern technology (video tapes, interactive computers, educational models) should be explored to improve undergraduate instruction.
- The university system could be used to bring selected new technology into the U.S. from leading foreign firms and universities through student and faculty exchanges.
- People are the key to technology transfer. Active industry participation is essential for successful exploitation of people as a resource.
- Industry involvement is also a key to targeting research for practical payoff.
- We must reevaluate public policy with respect to the long-term status of foreign graduate students in U.S. industry.
- Stability of federal funding is essential for the longer range evolution of technology.

GOVERNMENT

Relationship with Technical (Academic/Industrial) Community

Foreign competition is increasingly supported by its government in a variety of ways (subsidy, low interest rates, protectionist tariff, etc.).

For U.S. industry to remain competitive on the interantional scale, the U.S. government (1) must remove roadblocks to competitiveness, (2) be more supportive of research and development (tax credits, antitrust restrictions revision, etc.), and (3) assume a greater burden of cofinancing research and development.

National Laboratories

Approximately one-third of the total national R&D funds are allocated to the national labs. In an environment of strong competing demands for government funding, the labs must ensure that money is spent wisely. Funding has been provided to implement technology transfer requirements. There should be implementation of the Packard Commission's analysis of missions and goals of the labs to make sure they are in conformance with national goals in research and development. There should also be an effort to ensure that the R&D results are coordinated for more efficient use by other government agencies, academia and industry. It may be unrealistic to expect national laboratories to make continued direct contributions to short term industrial problems. The national laboratories' natural role is to add to the knowledge base through fundamental and mission directed research. The problem is to assure that national labs' new mission statements (not needed for defense labs) clearly define the particular area of fundamental and applied science which each lab should address.

Technical-Policy Interface

Considerable evidence exists that most policymakers do not adequately understand technical issues, their role in society, and the economic benefits they provide. Similarly, evidence exists that the technical community lacks desire to participate in the policy advocacy process. For the U.S. to enjoy competitive advantage in advanced materials, there must be more dialogue and understanding between the technical and policy communities.

State-Federal Relationships

States are becoming more active in funding R&D in electronic materials. A proliferation of programs has resulted. This activity should be more closely monitored so that results and information flow can be enhanced.

Recommendations

- The government should provide long-term, low-interest rate loans or loan guarantees for companies involved in advanced materials research.
- There should be a return to providing tax credits for research in advanced materials.
- The Packard Commission's report should be implemented.
- A mechanism must be developed to link the national labs to industries that can translate and utilize their research. Mission statements should define the area of fundamental and applied research which should be investigated. There should be careful choice of area to exploit needs for fundamental knowledge not provided by university and industrial research.
- With regard to policy and legislative affairs, the advanced materials industry should be more active in monitoring the policy process and designing strategies to further national interests.
- An interstate information-data base for improved information dissemination should be developed.
- There should be developed a mechanism and a forum for discussion to eliminate duplication and learn from each other's mistakes.

INDUSTRY

Industry Status

Development and innovation in the arena of commercially important electronic materials is strong, but implementation of advances into manufacturing continues to decline in the U.S. and is dominated by foreign concerns. For instance, the production of silicon and GaAs is increasingly being done off-shore and by foreign owned facilities on-shore. This seriously impedes the ability of the users of materials to turn domestic materials developments into commercial advantage. In the area of materials device production, initiatives have been launched to reverse similar trends; such initiatives are, for instance, SEMATECH, MRC, MCC, and various government funded centers. None of these initiatives specifically addresses materials production, and related materials processing. Manufacturing remains a low-prestige occupation. Furthermore, many industry laboratories are deemphasizing long-range research producing a long range technology gap. On a national basis, the resources employed are not optimally developed as there appears to be a good deal of redundancy in industrial supported research.

Industry: Barriers/Concerns

The tax and economic environment (impact of Wall Street) is not conducive to investment in capital intensive high technology materials production, and the initial capital investment

is usually targeted for its short-range profit potential since management rewards are linked to short-term return on investment. More applied positions, specifically those in manufacturing, are not prestigious in the U.S., and it is difficult to attract the best students into manufacturing technologies. Materials producers and materials users do not work in concert, and there is no mechanism for producers to share in high-value-added device processing.

Recommendations

- Reinstate tax credits for research.
- Encourage industry and academia to increase prestige of manufacturing engineering through:
  a. Focused educational requirements
  b. Provision for advancement of manufacturing engineers.
  c. Encourage continuing education emphasizing manufacturing engineering, instead of MBA.
  d. Change in "pecking order" of manufacturing vis-a-vis research, development and finance.
- Learning from programs of foreign governments, make available government seed money or loans to capitalize commercialization of semiconductor materials.
- Develop mechanisms for materials users to invest in materials production, e.g., through risk-sharing joint ventures.
- Reduce redundancy in industrial development by formation of an industrial coordination committee.
- Modify tax laws to make capital investment in materials production more attractive and less risky.
- Modify the management reward system to encourage long-term incentive and risk-taking.
- Reevaluate the mission of national labs by a panel of government and industry to better address industry problems.

CONCLUSIONS AND GENERAL RECOMMENDATIONS

- The nation's strengths in electronic materials reside in its depth of fundamental scientific understanding of the relationship between bonding, structure, and electronic properties. It is essential to continue support of these activities and in no way mortgage that support in response to other needs.
- The U.S. does not have a strong enough tradition in the synthesis and discovery of new materials. Solid state chemistry, new materials discovery, and characterization activities should be strengthened and enlarged.
- U.S. factory competitiveness in electronic materials production is perilously weak. Systematic efforts to build a body of knowledge in electronic materials processing science are essential. Improvement in the status of processing engineering in the factory is man-

datory and strategies to lower the barriers between the laboratory and the factory are urgently required.

- We applaud innovative collaboration between industry and the government to improve competitiveness as represented by the recently established Semiconductor Manufacturing Technology Center (SEMATECH). Although too early to judge its success, SEMATECH is intended to focus on major problems of semiconductor device manufacturing. However, more effort is desired on the effect of materials characteristics on subsequent device processing, performance, yield (cost) and reliability.

WORKSHOP SUMMARY

POLYMERS AND ORGANIC MATRIX COMPOSITES

THE HANDWRITING ON THE WALL

A significant opportunity for the U.S. to take a world leadership position in a lucrative market may be lost - and many U.S. jobs with it - if wise and coordinated action by government, industry and academia is not taken now.

The loss of metal and glass markets - and the jobs associated with these older, single phase materials - to thermoplastic composites and other new advanced structural materials is inevitable. These new materials can spur the necessary reduction in production costs and increase in performance to capture and grow a competitive edge in key markets, including aircraft/aerospace, automotive, industrial machinery and electronics.

"The value of components produced in the United States from these advanced materials has been projected to grow from about $2 billion in 1988 to nearly $20 billion by the year 2000. However, despite its strong position in advanced materials technologies (developed largely as a result of military programs), whether the United States will lead the world in commercializing these materials is uncertain...Potential U.S. commercial end users believe that major use of these materials will not be profitable for about 10 to 15 years, and have adopted a 'wait and see' attitude.

"In contrast, end user companies in several countries, notably in Japan, have initiated more aggresive programs to commercialize their evolving materials technologies, and have succeeded in bringing some advanced material products to the market years in advance of comparable U.S. products." (Report on Advanced Materials by the Office of Technology Assessment, June 1988).

That competitive advantage can only grow if the situation in the U.S. - where the triad of government, industry and academia too often regard one another as adversaries - does not change.

THREE KEY BELIEFS AND TWO KEY CONCEPTS

Positive action may be taken if the following beliefs and concepts are understood and accepted by all players.

Note: These beliefs and concepts were validated independently by three real world case histories presented in the workshop:

- Pontiac Fiero - presented by Hulki Aldikacti
- Hercules Rocket Motor Cases - presented by William G. Wilson
- V-22 Tilt-Rotor Aircraft - presented by Richard L. Grant

Belief #1 Development and commercialization of advanced materials is crucial to revitalizing U.S. industrial competitiveness and sustaining national defense.

Belief #2 The major issues in the field of advanced materials are not technological. They have rather to do with markets and the forces impacting those markets.

Belief #3 It is not enough for the U.S. to be a world leader in technology development; our future prosperity depends on capturing markets, based on developing, producing, and commercializing products that use that technology.

Concept #1: The "Specific Solution" or "What Drives the Market Chain?"

We have moved from the age of the "general solution" to the age of the "specific solution." We're not searching for another nylon - we're innovating new fabrics by combining engineered fibers; we're not after another aspirin - we're synthesizing drugs aimed at increasingly pinpointed targets inside the body; there is a bigger market for more adaptable personal computers than for bigger main frame computers.

The shift is pervasive. Material technology, to a much greater extent, drove the general solution. Today, it responds to the specific needs of the customer.

In fact, the consumer takes the materials for granted, as long as he gets the product he wants. In the case of the Fiero, he got a sporty commuter car with 50 mpg (A survey of Fiero buyers revealed the majority were not even aware that the body was plastic instead of metal). In the case of the V-22, the goal was an aircraft that can revolutionize commercial as well as military air travel.

Those who respond with the best solution to their customer's specific needs will capture the market. In the case of Hercules' rocket motor cases, long-term vision around a market led to building capability - that is, integrating vertically from materials through desien to production - that would meet escalating customer need (i.e., rockets to go further distances with more payload and greater fuel efficiency).

Concept #2: The "Systems Approach" of "How must the production chain work in order to produce these specific solutions?"

In the age of the "general solution," material suppliers could simply develop a material and "throw it over the fence" to the final part manufacturer, who took the material, designed his part and made it.

The process is exactly reversed to achieve the "specific solution." It is not a case of simply substituting one kind of material for another. Here, you begin by looking at the need and rethinking the best way to design and build to fit that need. You

create an intermediate form from those materials best suited to the task. The most important change, however, is that material selection, design and manufacture become inextricably linked. Those involved in each stage must maintain a dialogue.

In the U.S., we have plenty of materials to choose from, as well as the ability to develop manufacturing technologies. What must be strengthened, however, are the links along the production chain leading to the specific solution. Whether that takes the form of vertical integration within one company, as in the case of Hercules for rocket motor cases, or a much greater emphasis on teaming among companies and between industry and government, we must build closer associations to stay competitive.

Thus the keys to successful development and use of advanced materials are:

- vertically integrate/vertical partnerships between supplier and customer
- team it (share knowledge, cost, risk)
- combine product and materials understanding
- never look simply for direct material-for-material substitution
- keep communication open and honest
- always expect surprises

RECOMMENDATIONS FOR CONSTRUCTIVE ACTION

It cannot be emphasized too strongly that the U.S. is at a critical crossroads in determining whether it will be a leader or an also-ran in the multi-billion dollar advanced materials market.

- Some acceptable, legal vertical integration has to be allowed if advanced materials programs are to proceed with the kind of funding needed. No one company can do it all or afford it all. The industry can only advance on an integrated, or teamed, basis.

- Allow consortia for international development in the research areas to be formed; encourage legislation to allow the same thing domestically - and for manufacture as well as research (e.g., limited partnerships to create the necessary vertical integration, especially for big programs like the National Aerospace Plane).

- Industry needs to get more creative about making linkages (horizontal as well as vertical) within existing constraints, and government must encourage such linkages.

- One of the biggest differences between the situations in the U.S. versus Japan is the cost of capital. Thought should be given to redesigning the relationship of banks to the technology development and commercialization process.

- It is imperative that the tremendous conflict between DOD and the Department of Commerce positions on technology transfer and international cooperation/-competition be resolved. Industry gets caught in the crunch of competing priorities and philosophies. Fear of technology transfer outside the U.S. is overdone and harmful. It has, in documentable case after case, cut U.S. companies off from opportunities and handed them over to other countries. Further, it has soured potential partners in those countries from working with us in the future.

- Money is disproportionately handed out for R&D. Our goal is commercial development, but the lion's share of the resources comes from military pockets.

- We need programs to help universities get more money, and to help them interact with industry. While government should subsidize R&D (for example, matching funds going either to the university or the company), industry should drive program focus based on market knowledge.

- The advanced materials industry relies upon academia for people, ideas and tools. Universities should maintain depth in traditional disciplines and strength in basic research, but must provide multi-disciplinary experiences as well. Cooperative industry/academic programs and interchanges are required to do this. Isolation creates a lack of perspective.

- The national laboratories are also treasure troves of experience, capability, and ideas. Industry must find ways to partner with these labs in innovative ways that build on specific expertise (e.g., computing capability at Los Alamos). Labs have to be able to partner with competing companies at the same time. Industry has to seek these linkages proactively and be ready to pay for them, while the labs must encourage this rather than view industry as competition for funds.

- Corporate management now works on a reward system based on short-term performance; this should be restructured to focus on the long term - thus encouraging the patience, risk-taking and investment of significant resources required to win in the advanced materials market.

- Government can encourage long-term thinking by corporate management through careful policy making that balances incentive/reward (e.g., around investment, proprietary rights, consortia, etc.) versus regulation.

THE POWER OF PARTNERSHIPS

National leadership to drive an advanced materials policy is required. Alignment of industry, government, academia - and the public interest - is necessary to achieve such a policy. Today, the lack of public trust has led to large, bureaucratic structures that impede efficiency, industrial risk taking and international competitiveness. Discussion and action must move outside just the research community and into a business forum.

- Priorities must be set that are clearly focused on specific goals and markets.

- Top management from the advanced materials industry should be brought together to focus attention on those priorities.

- These industry leaders, in turn, must reach government leaders to mobilize key organizations: Among them, the Secretaries of DOD, Interior and Commerce, along with representatives from the White House and both houses of Congress.

- Together with university leaders, industry and government chiefs must set the course for a win-win-win national policy on advanced materials.

- Finally, we must identify and build a constituency for support among the public. We must find a way to engage the public interest and imagination by making

clear the link between a strong position in advanced materials and a strong future for American industry and the national defense.

One possible U.S. model is the semiconductor industry: it took the personal involvement of the Chairman of IBM who rallied other leaders in his industry, who in turn rallied DOD and Congress to their cause. Coupled with very strong lobbying by their materials technology organization, they were able to create the necessary vertical integration to break the crippling stagnation that had set in.

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ing/commercialization of low temperature superconductor devices.

5. What are the roles of Industry, Academia and Government in eliminating these hurdles?

   a. A long term, interdisciplinary collaboration is needed between industry, academia, and government.

II. GOVERNMENT-SUPERCONDUCTIVITY

Tax Policy

Tax policy should encourage research and development and capital investment. Because of the long time frame required for commercialization of technology, these tax policies should be available on a sustainable and consistent basis. The "on-off" approach to R&D and capital investment, and the resulting uncertainty makes it difficult for corporations to commit to the long term planning horizon required to exploit superconductor technology. The perceived commercial potential of high temperature superconductors has elicited a large amount of entrepreneurial activity. Specific R&D and capital investment policies that support this activity should be encouraged.

Advanced Materials Development - Defense and Non-Defense Related R&D

1. Mechanisms should be established to accelerate defense related R&D spin-offs.
2. NSF funding for superconductors should be significantly increased without penalizing other programs.
3. Government support of R&D should emphasize materials development and proof-of-concept, but not the actual commercialization of products.
4. Uncertainty of the time frame for commercialization and the current state of technology requires diffuse research support which can be adequately provided by existing funding.
5. R&D support should be provided to both large interdisciplinary groups as well as individuals and unstructured groups of a few individuals.

Policy

1. Free and open exchange of basic information should not be inhibited.
2. The Congressional Caucus on Competitiveness should be encouraged to visit the leading overseas countries in advanced materials R&D to obtain a first-hand knowledge of their commitment and support.

III. CORPORATE/INDUSTRIAL

Obviously, the primary responsibility for commercialization of superconductivity lies with industry. However, a problem exists in the corporate role in superconductivity development, as well as in other advanced materials areas:

1. Lack of vision and commitment with respect to the long-term importance of materials, processing, and manufacturing.
2. External financial pressures brought about by such factors as the cost of capital, Wall Street, and variable tax policies often face short-term decisions.
3. Segmentation, duplication, and complex requirements of the technology that strains capabilities of small companies.

Recommended approaches to ameliorate these issues:

1. Encouragement of horizontal and vertical technology collaboration.
2. Identify the characteristics of successful collaborative efforts and more broadly implement them to ensure effective industrial involvement (e.g., in science and technology centers, national laboratories, EPRIs).
3. Government funding support to encourage superconductivity development which has the following key characteristics:
   a. "Precompetitive" technology development
   b. Collaborative vs. universities and national laboratories
   c. Cost shared by industry
   d. Industrial personnel involvement

IV. ACADEMIC CHALLENGE

Universities are anxious to teach and perform research in a multidisciplinary fashion. Specifically, the following are proposed:

1. An undergraduate education emphasizing basic science is vital. Multidisciplinary studies will be most effective when added to a rigorous basic science and engineering education. Advanced materials and superconductivity need to be emphasized at the graduate level.
2. Advanced materials, many of which may be expensive, exotic, brittle, or otherwise hard to handle, need to be integrated into devices. Design is an integral part of materials studies.
3. Materials education will benefit from research funding which positively encourages small collaborations (e.g., two to five faculty, industry or national laboratory groups) with opportunities for interchange of students and staff.
4. Universities must have larger, more stable basic science funding whose prime aim is the discovery and understanding of advanced materials. They could be given attractive incentives of increased funding (e.g., in fashions similar to those used in the Presidential Young Investigators Program or the forthcoming DOE Superconductor Pilot Program).
5. The research universities have been doing a good job so far in aggressively tackling R&D problems of HTSC. However, this effort should not be taken for granted in the future; there is insufficient money to support all the proposals for work in HTSC and continued high performance cannot be assured without increasing support.
6. The best research universities have been doing a good job in technology generation and transfer. Universities such as Stanford and the Massachusetts Institute of Technology have effective industrial affiliate programs that provide a healthy environment for interactions between students, faculty, and industry researchers. These models could be emulated with profit by other universities. However, while industry problems can provide useful intellectual feedstock for Ph.D. student projects, decision responsibility for such projects must remain with the faculty and students. By and large, industry recognizes this, and appreciates the long-term benefits from this system.
7. There is an issue of "critical mass" associated with materials R&D. This suggests that aggregations of some sort may be desirable, whether engineering research centers, materials research groups, or science and technology centers. A mix of a few centers with a broader distribution of individual investigator groups

is desirable. Centers can provide the multidisciplinary environment that is crucial to solving many materials problems. They should not be viewed only as sources of technology that can be directly commercialized by member companies. Rather, the industrial participants are primarily interested in access to graduate students and smart faculty to give them a window on new developments in the best universities. Thus, such centers should be seen as infrastructure support, rather than engines of commercialization and jobs. This infrastructure contribution is essential and should be continued. However, the burden of research should remain with the individual investigators, the model that has worked so well in the past.

Coordination of major research universities will be difficult. The long-term trend of bigger materials departments is very desirable, since this is the most effective way of making materials education multidisciplinary. Within the framework of approximately-fixed university budgets, horsetrading by neighboring universities may be one method of increasing the size of materials departments.

There are major problems of undercapitalization and insufficient permanent staff in all the research universities. Achieving a smaller number of critical size efforts is much more important than increasing the number of subcritical efforts.

SAMPE.
Society for the Advancement of Material and Process Engineering

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June 21, 1991

Honorable Tim Valentine
Chairman
House Subcommittee on Competitiveness
and Technology
2325 RHOB
Washington, DC 20515

Dear Mr. Chairman:

Attached you will find the comments of the Society for the Advancement of Materials and Process Engineering (SAMPE on Critical Technologies-Materials. SAMPE applauds you for holding hearings on these vital technologies and offers for you consideration three recommendations for spurring the further growth of this industry within the United States. Although these recommendations may at first appear to be innocuous, they are vitally important in terms of enabling this industry to exploit non-defense applications in this country.

Again we thank you for your stalwart support of our industry and we look forward to working with you in the months ahead.

Sincerely,

Thomas R. Goldsmith

Dr. Charles Hamermesh
Technical Director

CH/sam

Comments of The

Society for the Advancement of Materials

and Process Engineering

Submitted to the

House Subcommittee on Competitiveness

and

Technology

21 June 1991

SAMPE appreciated the opportunity offered by the Subcommittee on Competitiveness and Technology to provide additional testimony on the Critical Technologies-Materials industry. SAMPE supports the efforts of this committee and encourages the committee to incorporate the recommendations contained herein in its proposals to Congress.

The Society for the Advancement of Materials and Process Engineering (SAMPE), founded in 1944, has approximately 12,000 members, all of whom are associated with some aspect of advanced materials and processes industries. The mission of SAMPE is to provide, in an unbiased manner, technical information in regard to this arena. Over the past decade, SAMPE has firmly established itself as the preeminent organization in the field of composites.

Composites, a combination of reinforcing fibers and synthetic resins which provide excellent performance even in extreme environments, are used in a variety of weapons systems which were successfully employed in Operation Desert Storm. Among these systems are the AV8B-Harrier jump jet, F117 Stealth fighter, the Patriot missile, the Bradley armored personnel vehicle, and the TOW and Stinger missiles. To a considerable extent, the performance of these weapons is directly attributable to the composite components contained therein, thus demonstrating that the United States is the leader in critical technology. However, America's lead is relatively short and could be expunged rapidly (1-2 years) if the growth of this technology, and the industries and individuals which serve it, is not encouraged.

This critical technology also offers an opportunity to improve the competitiveness of the United States in the global composites market which encompasses not only defense and aerospace where these materials were developed initially but also the non-defense areas such as industrial, recreational, electronics, and automotive. While some penetration of these markets has occurred, it has been quite limited.

The constraints to market enhancement for composites are twofold: (1) the lack of know-how of potential users in regard to composites, and (2) the present shortage of trained materials technologists available to work in these areas.

The problem relating to the lack of know-how of the potential user is quite clear. If a company which currently produces metal parts is not fully aware or informed of the advantage which could be devised from switching to composites, there is little likelihood that it will attempt the conversion. Much of the constraints which impede the transfer of knowledge occurs as a result of national security classifications and controls which were imposed upon advanced materials in the early 1980s. These controls often prevent DOD sponsored R&D from moving from mature defense programs to the commercial sector. The severity of controls has led to circumstances which, as Dr. George Mibourne, Executive Vice-President of the National Center for Advanced Technology stated in his oral testimony before the Subcommittee June 11, 1991, either require commercial firms to reinvent technologies or forgo such applications. His example regarding the inability of defense contractors from commercializing technologies, some of which are over ten years old, strikes at the heart of our nation's ability to compete in markets at home let alone abroad in industries our government has called critical to our national economic well-being and future defense capabilities (see: Department of Defense Critical Technologies, Plan for the Committees on Armed Services of the United States Congress - AD-A234-900 May, 1991, pages 1-1 - 1-18; 10-1 - 10-9; 14-1 - 14-23; and 18-1 - 18-16. Report to the President of the National Critical Technologies Panel, March, 1991, pages 7-27).

Even assuming that this information gap is filled and the non-enthusiastic potential user wants to go over to composites, the current limited number of available trained materials technologists will hamper these attempts, which may so frustrate the user that it could result in abandonment of the conversion effort.

Probably, the most difficult part of this technology transfer is the identification of the market niches where composites could perform effectively. With the exception of the automotive area, which while it is a potentially huge volume user, is a very slow developing area, the

other markets are so diverse, and in many instances, relatively small (by themselves), that the costs to research and identification can act as a deterrent to most companies because the payoff based on the short term is often insufficient to warrant the "up front" expenses. However, and unless this market research is performed, the U.S. will be pushed aside by foreign countries where the combinations of government and industry are willing to pool their funds to examine and explore markets and to identify specific needs.

Assuming that the U.S. (government and/or industry) were to identify niche markets, the final step would be to determine the annual volume required, the ability to produce composites of the type required in those volumes, the ability to maintain an acceptable level of quality in such components produced at this rate, and the cost effectivity of such composite components compared to parts made of more conventional materials. Once factors are determined, work can then begin on solving those problems which will allow for rapid market penetration.

Where does the government come into this attempt to improve the U.S.'s competitiveness? In the education, information, and market research aspects. Namely, SAMPE recommends that the government fund a national undergraduate program to train more materials technologists. Furthermore, it recommends that the government ease classification and control regulations for mature technologies so as to facilitate the transfer of know-how of potential commercial users. And, finally, that the government contract a technically capable market research organization to survey and identify the possible markets for composites.

It is SAMPE's opinion that the critical technology of materials, more specifically, composites, can serve as the basis for improving U.S. competitiveness in the fast growing global market. SAMPE is prepared to provide unbiased information and, if desired, assessment thereof, to the Committee to help it formulate a sound and logical program to help in the transfer of this critical technology to the commercial sector where it can help improve U.S. competitiveness.

518 2nd St. SE #3
Washington, DC 20003
June 13, 1991

The Honorable Tim Valentine
Chairman House Subcommittee on
Technology and Competitiveness
1510 Longworth HOB
Washington, DC 20515

Dear Mr. Valentine,

In response to your open invitation for commentary on the June 11, 1991 Subcommittee on Technology and Competitiveness hearing covering advanced materials, I would like to expand on testimony given by Dr. Mary Good.

During the question and answer segment of the hearing, Dr. Good discussed the aerospace industry qualification of advanced materials as an effective means to move advanced materials toward market maturity. High performance, reliability and other material requirements place the aerospace industry in a lead role in structural materials development. However, current Federal Aviation Administration (FAA) regulations make it difficult and very expensive to qualify new materials for aircraft use.

Through federal research programs, the government could assist in basic materials qualifications and substantially reduce the certification costs incurred by aircraft companies. A standardized data base of material properties would encourage the use of new materials by making certifiably accurate material property data readily available for engineering use.

Currently, The Department of Defense (DoD) military handbook series (e.g. MIL-HDBK-5 (metals), MIL-HDBK-17 (plastics/composites), and the Damage Tolerance Handbook) is the only standardized, acceptable material database available. The database, however, lags far behind materials development and therefore includes virtually no material property data on composite materials, metal matrix materials, ceramics and other recently developed materials.

A coordinated U.S. Government materials testing program directed by a joint industry/government steering group could produce the much needed standardized advanced materials property data. The testing program would be an extension to ongoing government materials development research with much of the necessary testing equipment and qualified personnel already present at national laboratories. Steering group responsibilities would include:

- Compiling a standardized database of certifiably accurate material properties.

- Coordinating federal and affiliated private materials testing to prevent duplication of effort.

- Standardizing testing techniques.

- Consolidating previous certifiable U.S. Government and industry materials test results for inclusion in the standardized materials data base.

- Conducting material property tests on U.S. Government developed materials and on joint government/industry developed materials.

- Actively encouraging industry submittal of qualified material property data for inclusion on the standardized materials data base.

- Ensuring provisions are made for certifiable materials testing in federal grant materials development programs.

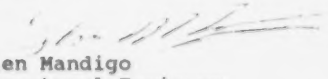
- Administering a materials testing grant program to cover materials testing techniques and encourage publication of material property data on certain advanced materials.

Expected costs for such a U.S. Government materials testing program would be relatively low as much of the necessary infrastructure is presently in place within the DoD and national laboratories. Industry cooperation and engineering society technical support would also help to reduce program operating costs. Materials testing grant program funding could be obtained by setting aside a percentage of appropriated funds marked for materials research and development.

The establishment of a current standardized database of certifiably accurate material properties would encourage the use of new, advanced materials by the aircraft industry. The database would significantly reduce material certification costs to aircraft manufactures and provide design engineers with a reliable, acceptable reference for materials data. As Dr. Good mentioned, once established in aerospace markets, aerospace qualified materials often find broader industrial applications.

Thank you for this opportunity to comment on the Technology and Competitiveness Subcommittee hearing covering advanced materials. I strongly support your efforts to promote the competitiveness of the American materials industry.

Sincerely,



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June 6, 1991

JUN 11 1991

The Honorable Tim Valentine (D-2-NC)
Science, Space, Technology House Committee
1510 Longworth House Office Building
New Jersey and Independence Avenues, SE
Washington, DC 20515

Dear Congressman Valentine:

As probably the only academic materials scientist who has been involved in national technology policy evaluation for over two decades, I am delighted that you are holding hearings on critical *materials* technologies. I am the only person who has served on both the National Academy Committees on Materials (COSMAT in 1973 and MSE in 1989). I am a frequent visitor to Japan and knowledgeable about the status of their MSE research. I have been honored by several of their high-tech organizations.

From this background I must say that I find the lack of national planning of technology policy not only appalling but positively frightening in the world of globalized technology.

I am very impressed by the fact that you have particularly singled out Lanxide technology as one to be focussed on by inviting its discoverer to testify. Here is a unique, major, American discovery in materials technology. If we cannot—in our free market plus government policy system—preserve this technology for the nation's gain there is something crazy about the system. At the other end of the spectrum is diamond film technology which I—because of my connections—happened to bring from Japan (and the USSR) to the U.S.

Now CVD diamond films constitute an absolutely here and now technology. New products—all from Japan—are introduced every month. The technology penetrates many disparate fields from cutting tools to acoustic speakers, from heat sinks for semiconductors to scalpels for eyes. The markets are safely expected to reach a volume of several billion dollars by 2000 A.D. New challenges loom—for active and passive roles for diamond in semiconductors.

Yet with total disregard for the market, research balance, or common sense, the Federal government spends ~$150 million on ceramic superconductor research, and only $10 million on diamond research. What is the rationale for such an allocation? Some months ago I pulled together a White paper on diamond films. I believe your staff will find this helpful, and your

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committee might well choose to deal explicitly with what policies will stimulate our Federal agencies to move ahead strongly to make up for the least expense.

I will be happy to supply any further information you may desire.

Sincerely yours,

Rustum Roy
Evan Pugh Professor of the Solid State

cc: Congressman D. Ritter
Chair, G. Brown
Congressman R. Walker

DIAMOND FILM SCIENCE AND TECHNOLOGY

A TEST CASE FOR U.S. CIVILIAN TECHNOLOGY POLICY

A White Paper

by

Professor Rustum Roy
The Pennsylvania State University

August 1990

Derjaguin and his colleagues continued systematic work for 20 years and finally in the mid-seventies came up with the key discovery that made continuous growth of polycrystalline diamond film from a vapor on a variety of substrates, possible. This discovery was simply that atomic hydrogen was a "solvent" for graphite and did not affect the diamond as it was deposited. Derjaguin's discovery made available in many papers and books was completely ignored worldwide. Except in Japan, where in the National Institute for Research in Inorganic Materials (NIRIM), Matsumoto, Setaka, Sato et al. modified the process into a reproducible engineered method for depositing thin films of (10+μ) of crystalline diamond over several square inches. Their published (in U.S. journals) work and patents were also ignored in the U.S. and by and large the whole world.

The present author (who had also previously ignored the published work) on a visit to NIRIM in Tsukuba, Japan, in February 1984 was shown the microwave reactors and the spectacular results on diamond film preparation. On his return he communicated his very strong impressions to Federal agencies and to colleagues at G.E. and also visited his colleague Professor Derjaguin in Moscow. In 1985, the Office of Naval Research funded him to duplicate the work. By February of 1986 our first diamond films were being made routinely. Yet it took several months to convince the U.S. community of the reality of our duplication of the Soviet-Japanese development. In the Fall of 1986, Penn State's MRL inaugurated a Consortium of (nearly exclusively) U.S. companies to which we effectively and rapidly communicated our knowledge. They in turn supported the research on process optimization, in parallel with continuing fundamental research support from ONR and SDIO via ONR. By Penn State convening the usual scientific meetings and by ONR's involvement of other laboratories, this proved to be a very successful example of knowledge transfer, to industry, whereby a dozenU.S. companies got a start on their diamond film work. We note in passing that this is an increasingly significant model for U.S. institutions since the original work was NOT done at Penn State. The University here served its original role of the gatherer, organizer, amplifier and effective transmitter of knowledge, rather than only its generator.

Status of Diamond Film Research Today

Diamond films have become today a world-recognized prototypical enabling technology.

First, it should be very strongly emphasized that diamond film deposition is a generic process discovery. It has implications for, and applications in, literally dozens of very, very different technologies and businesses.

Second, it should be emphasized that it is a remarkably versatile, user-friendly process easily duplicated in many different variations.

Third, it must be understood that these applications are NOT to some esoteric super specialized-space or defense-related application, but in the everyday large volume technologies of coating cutting tools, acoustic speakers, coating eyeglasses, and also making thermal management substrates for high-density semiconductor chips.

Fourth, it must be understood that all these applications are already appearing on the market as products for Japanese companies. The line-up of possible future products is nearly endless (and mainly in exoteric fields). But diamond has also the possibility of becoming the third generation active semiconductor material (after Si and GaAs).

In technology in 1990, Japan is very substantially ahead with at least 50 major corporate efforts and solid government work. In scientific research and understanding, the U.S. is now on a par with Japan. Europe and the USSR have made a later entry into the applications but in 1990 are moving rapidly.

The Public Policy Issue

One hardly needs to invoke the specter of "industrial policy" to know that **the Federal government must have some kind of coordinated R&D policy response to a major enabling technology discovery of this magnitude**—which in the opinion of most materials scientists who have compared the two far outranks the high T_c superconductor today and in their very probable relative impacts in the next 10-15 years.

The Federal government spends $150 million on superconductor research (as is estimated). What then is the appropriate support of diamond research. It is estimated that a total of about $10-12 million is being spend today, perhaps over 80% by the ONR (which backed the original U.S. entry via Penn State in 1985). Surely an immediate coordinated effort built up to the same level as superconductor research over the next 2-3 years would be a reasonable response. As a materials policy analyst I would add that some of that need not be new money. The Federal government spent much larger sums annually on ceramic engine materials for 20 years. The superconductor research paid for by industry—which is the safest index of its likely value in the 10 years—is very substantially down from its peak. Some of that money (although not the groups) and other SDIO materials efforts could be redirected to diamond film work.

Most significantly, it is certainly obvious that the role of the Federal government in funding the **highest risk basic work** (e.g. radically new processes, or radically new materials which **surpass diamond) offers the only hope of leap-frogging the international competition**. It is certain that U.S. industry will not fund such work. Other research directed to specific mission agency targets (e.g. i-r domes; thermal management, corrosion resistance) can very easily become part of a coordinated team effort.

JAPAN'S MARKET SHARE OF MATERIALS RESEARCH

I. CERAMICS

Rustum Roy, M. Silsbee and H. McKinstry
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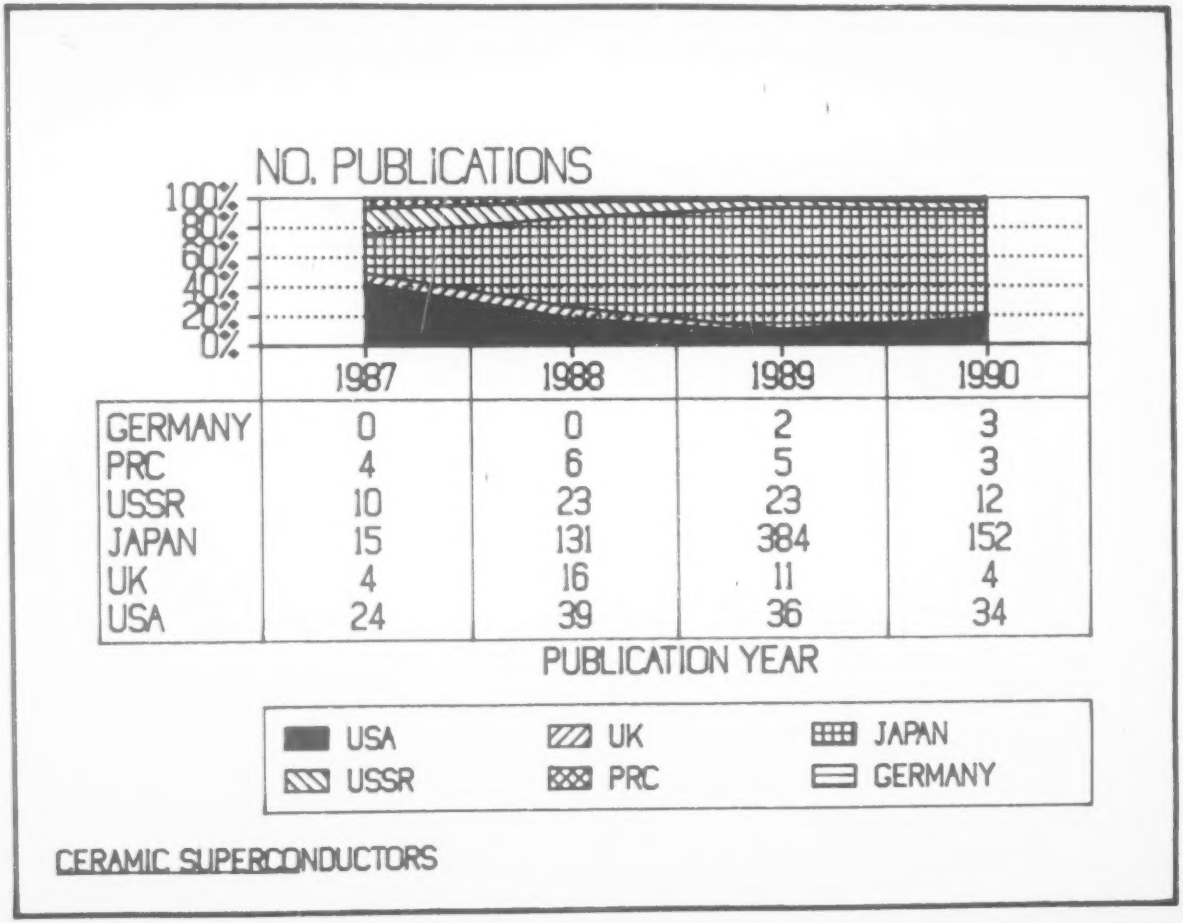
ABSTRACT

A very simple comparative assessment of the contributions by various nations to the research in various sub-fields of ceramics, and in their total, has been carried out using the computerized (U.S.) *Chemical Abstracts* database.

The number of abstracts of research published in each subfield by scientists from 5 different major advanced countries, and China, certainly provides a first-order approximation of the research effort (and output, although not necessarily of quality) by that country.

The accompanying graphs show an almost unbelievable dominance in many, not all, subfields of (ceramic) materials research by Japan. In several fields including ceramic superconductors, the Japanese produce 60-70% of all the papers. However, surprisingly in perhaps the most economically significant, and least visible subfields in the U.S., zeolites, the Japanese have their lowest market share.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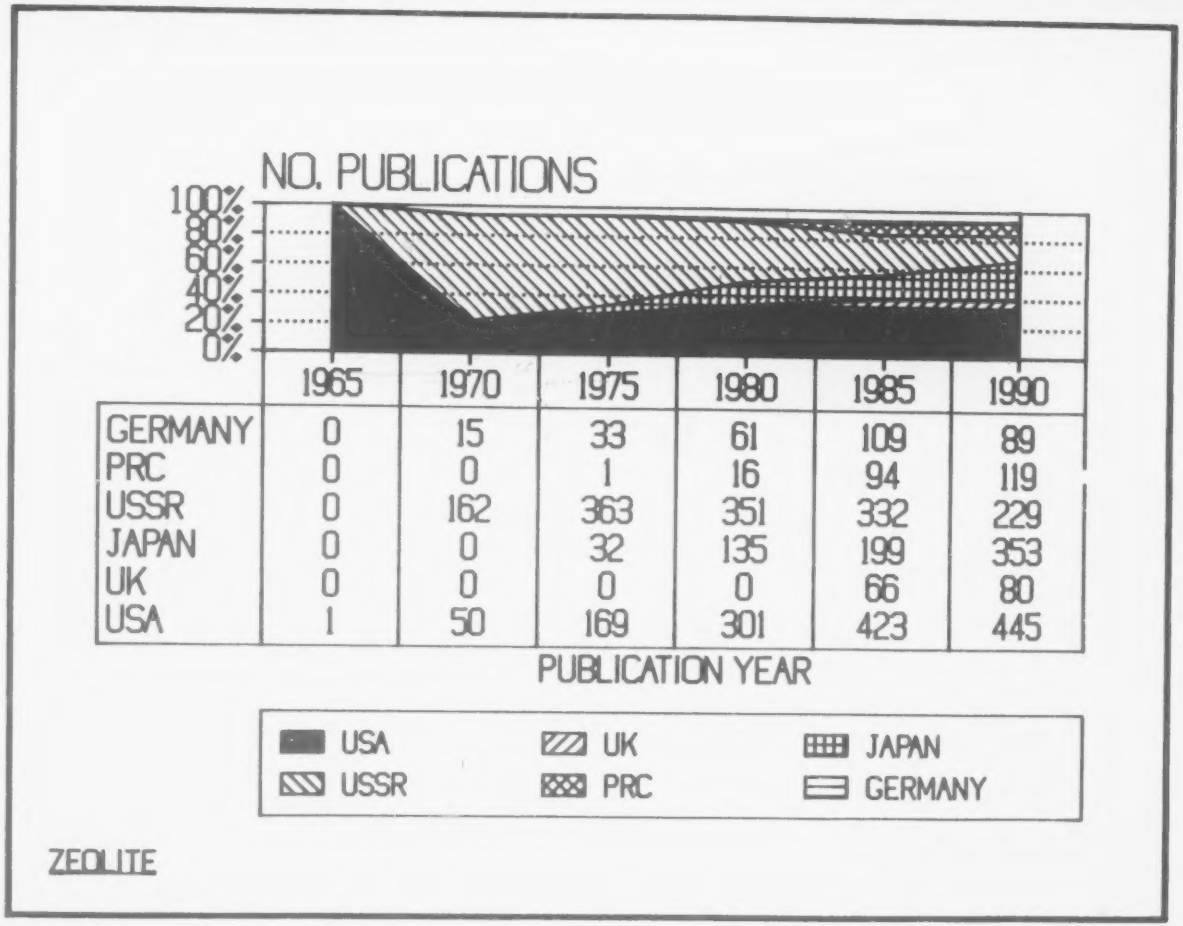
CERAMIC SUPERCONDUCTORS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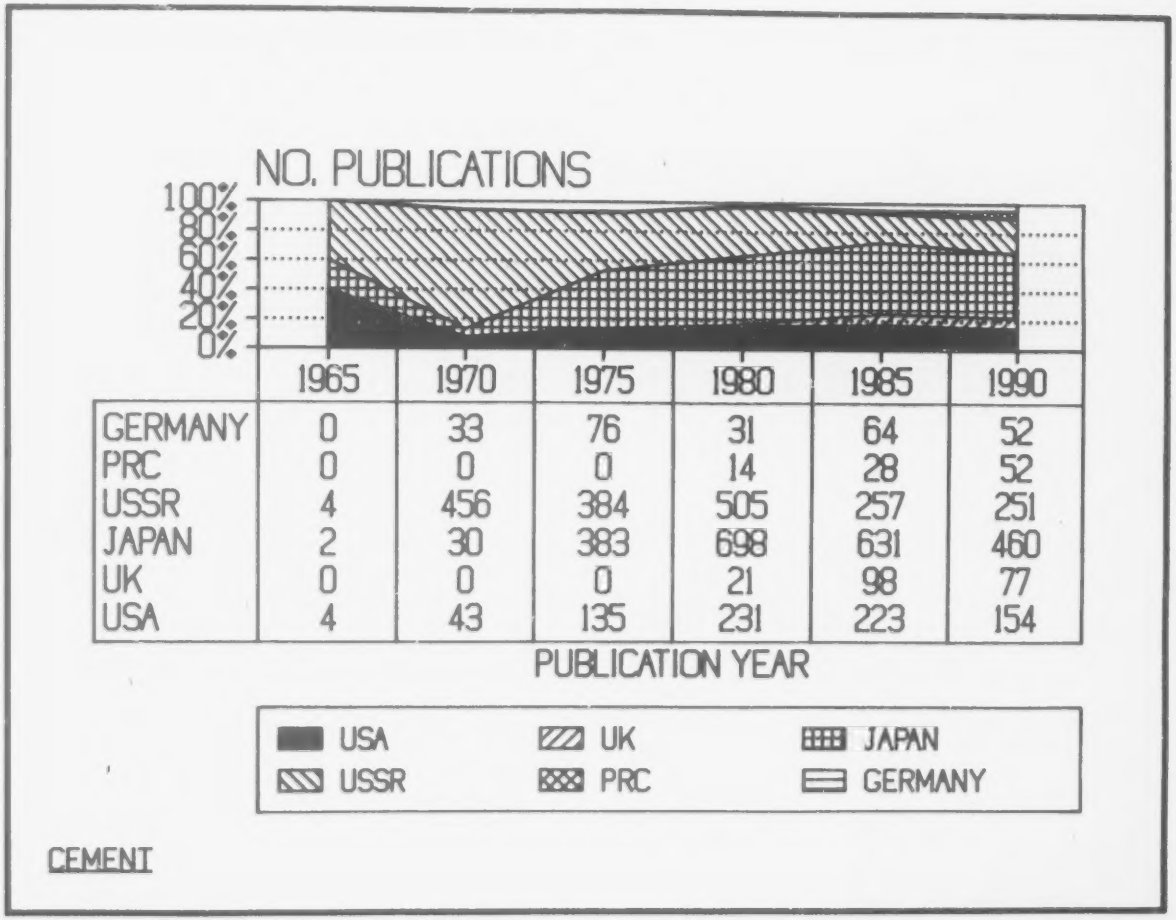
ZEOLITE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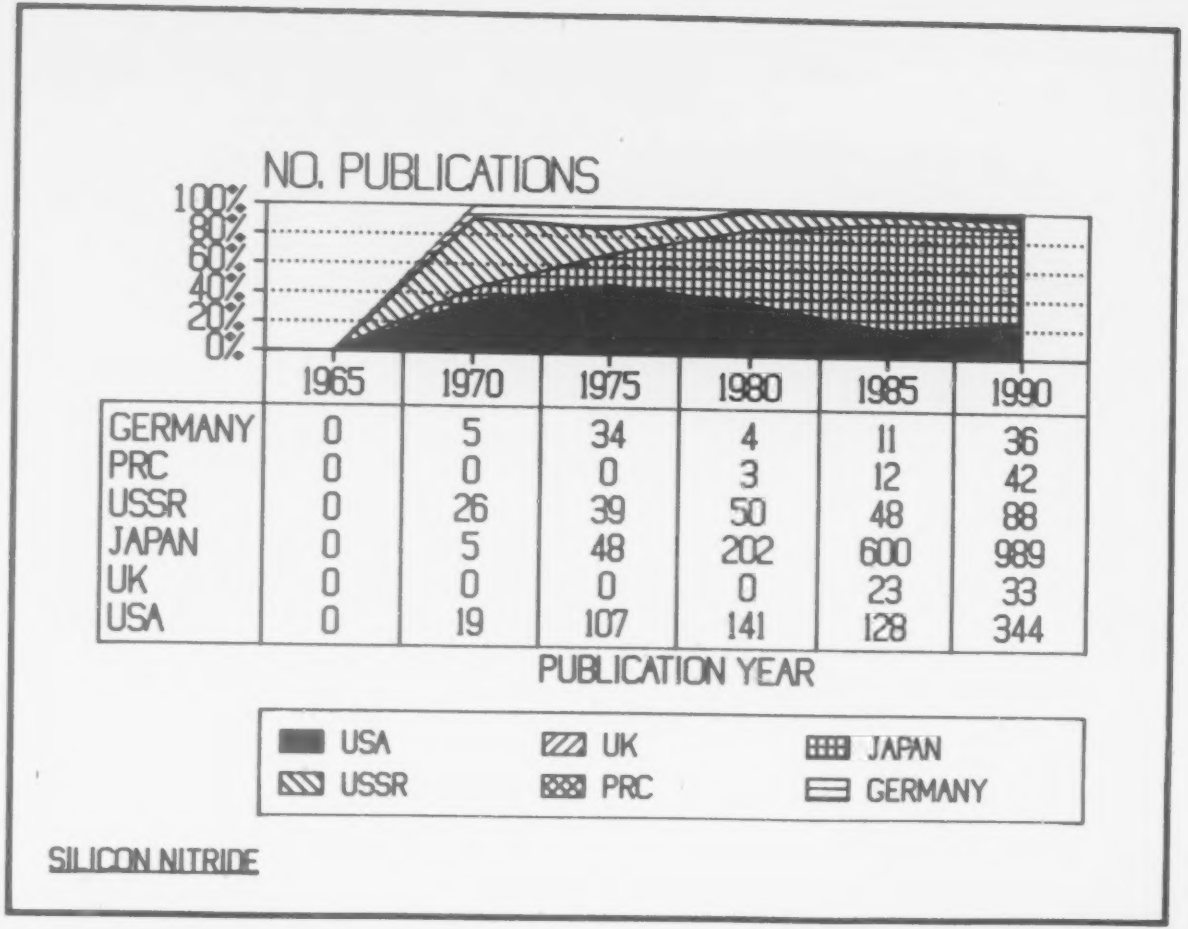
SOL GEL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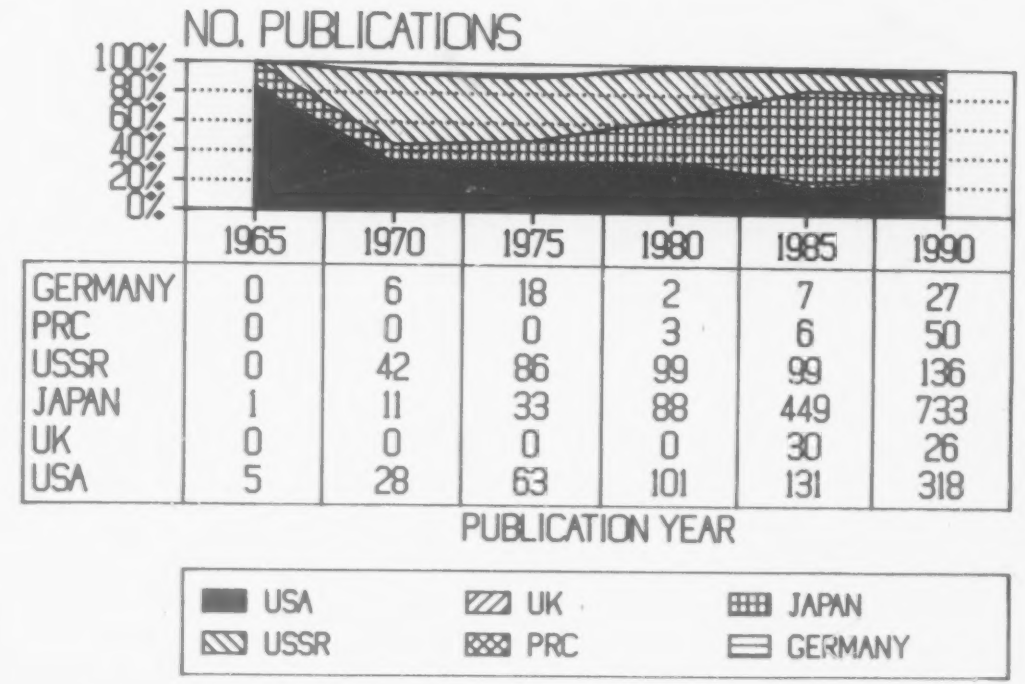
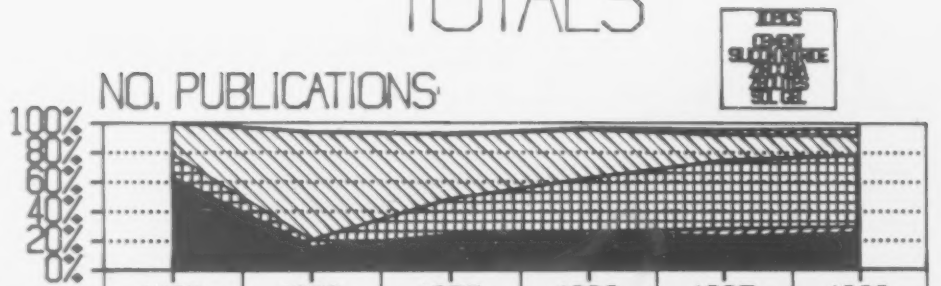
SILICON NITRIDE



	1965	1970	1975	1980	1985	1990
GERMANY	0	6	18	2	7	27
PRC	0	0	0	3	6	50
USSR	0	42	86	99	99	136
JAPAN	1	11	33	88	449	733
UK	0	0	0	0	30	26
USA	5	28	63	101	131	318

ZIRCONIA

TOTALS



	1965	1970	1975	1980	1985	1990
GERMANY	0	61	162	98	193	206
PRC	0	0	1	36	140	279
USSR	4	687	876	1028	738	719
JAPAN	3	49	496	1124	1941	2758
UK	0	0	0	21	220	228
USA	12	144	476	781	945	1422

CEMENT

	USA	UK	JAPAN	USSR	PRC	GER
1965	4	0	2	4	0	0
1970	43	0	30	456	0	33
1975	135	0	383	384	0	76
1980	231	21	698	505	14	31
1985	223	98	631	257	28	64
1990	154	77	460	251	52	52

ZEOLITES

	USA	UK	JAPAN	USSR	PRC	GER
1965	1	0	0	0	0	0
1970	50	0	0	162	0	15
1975	169	0	32	363	1	33
1980	301	0	135	351	16	61
1985	423	66	199	332	94	109
1990	445	80	353	229	119	89

ZIRCONIA

	USA	UK	JAPAN	USSR	PRC	GER
1965	5	0	1	0	0	0
1970	28	0	11	42	0	6
1975	63	0	33	86	0	18
1980	101	0	88	99	3	2
1985	131	30	449	99	6	7
1990	318	26	733	136	50	27

SILICON NITRIDE

	USA	UK	JAPAN	USSR	PRC	GER
1965	0	0	0	0	0	0
1970	19	0	5	26	0	5
1975	107	0	48	39	0	34
1980	141	0	202	50	3	4
1985	128	23	600	48	12	11
1990	344	33	989	88	42	36

SOL GEL

	USA	UK	JAPAN	USSR	PRC	GER
1965	2	0	0	0	0	0
1970	4	0	3	1	0	2
1975	2	0	0	4	0	1
1980	7	0	1	23	0	0
1985	40	3	62	2	0	2
1990	161	12	223	15	16	2